DESIGN ANALYSIS

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BASIN F LIQUID STORAGE TANK 102 DECONTAMINATION FIELD DEMONSTRATION ROCKY MOUNTAIN ARSENAL, COLORADO

Prepared for
U.S. Department of the Army
Corps of Engineers, Omaha District
Omaha, Nebraska
July 1992

Woodward-Clyde

Woodward-Clyde Consultants
101 S. 108th Avenue
Omaha, NE 68154

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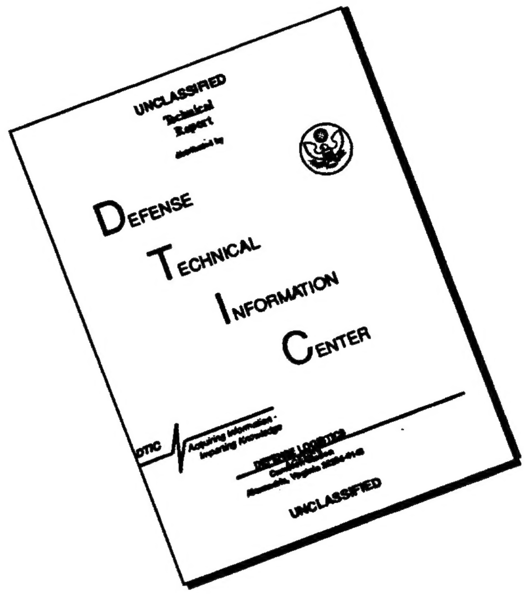

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1.0 INTRODUCTION

Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Program Manager for the Rocky Mountain Arsenal (PMRMA) is implementing the final disposal of the liquid removed from the former Basin F surface impoundment. This liquid is presently stored in three tanks and one pond. During storage of the Basin F liquid, crystals have precipitated from the liquid and accumulated in the bottom of the tanks and pond. These crystals will require removal and the tanks and ponds must be decontaminated and dec .mmissioned after removal of the Basin F liquid.

The Basin F liquid has been characterized and a remedial alternative has been selected for its final treatment and disposal. A Submerged Quench Incinerator (SQI) is being constructed for incineration of the liquid.

An alternatives assessment of the crystal removal and tank decontamination/decommissioning is being conducted as part of the IRA process, and was submitted in Final Draft form in March 1992. The report contains recommendations for both the ponds and tanks. Mechanical removal as well as dissolution alternatives were evaluated for feasibility and cost effectiveness. The recommended action at the tanks was to pilot test, in one of the tanks, the in situ dissolution of the crystals with heated water after the majority of the Basin F liquid was removed. After dissolution of the crystals and removal of the dissolution liquid, the tank liner, geonet, and appurtenances would be spray washed, removed and packaged for disposal. Then the tank and its roof would be decontaminated. Tank 102 was the logical selection for this test/demonstration as a result of the presence of Basin F liquid in the leak detection system of the tank.

This Preliminary Design Analysis for the Basin F Liquid Storage Tank 102 Decontamination Field Demonstration has been prepared as part of the Interim Response Action (IRA) at the Rocky Mountain Arsenal. This report contains the engineering criteria and design information applicable to the demonstration of the in situ dissolution of the crystals and decontamination of the tank.

1.1 BACKGROUND

Rocky Mountain Arsenal (RMA) occupies more than 17,000 acres in Adams County, Colorado northeast of metropolitan Denver. The property was purchased by the U.S. government in 1942 for use during World War II to manufacture and assemble chemical warfare materials and incendiary munitions. A significant amount of chemical warfare materials destruction took place during the 1950s, 1960s and 1970s. The last military operations ended in the early 1980s, and in November 1988, RMA was reduced to inactive military status reflecting the fact that the only remaining mission at the RMA is contamination cleanup. In addition to these military activities, major portions of the plant facilities were leased to private industries, including Shell Oil Company, for the manufacture of various insecticides and herbicides, between 1947 and 1982.

Disposal practices at RMA have included routine discharge of industrial and munitions waste effluent to evaporation basins. Spills of raw materials, process intermediates, and final products have occurred within the manufacturing complexes at RMA. In 1956, Basin F was constructed in the northern portion of RMA. Basin F had a surface area of 92.7 acres and a capacity of approximately 243 million gallons. The basin was created by construction of a dike around a natural depression and was lined with a 3/8-inch catalytically blown asphalt membrane. An earthen blanket approximately 1 foot thick was placed on top of the membrane to protect it. A vitrified clay pipe with chemically resistant sealed joints was installed between Basin F and the facilities where the wastes were generated. From August 1957 until its use was discontinued in December 1981, Basin F was the only evaporative disposal facility in service at RMA.

In 1986, the Department of the Army, Shell Oil Company, and the EPA Region VIII agreed that an accelerated remediation be conducted to contain the liquid and contaminated soils in and under Basin F.

The first Interim Response Action (IRA-1) for the Basin F liquid, sludge, and soils remediation resulted in the present situation with the Basin F liquid being stored in three lined storage tanks and one lined surface impoundment. The second Interim Response Action (IRA-2) addresses the treatment and disposal of the contents of the storage tanks and pond. This IRA was initiated in September 1988 and is in progress.

1.2 SITE DESCRIPTION

The tank farm lies at the southwest corner of the intersection of 9th and D Streets. The tank farm is comprised of three tanks numbered 101, 102, and 102. The three tanks are similar in size and design, and were built in 1987. They contain a total volume of about 4,000,000 gallons of Basin F liquid, each tank containing approximately 1/3 of the total volume. The tanks are 78.5 feet in diameter and about 40 feet in height. The tanks are lined with a 100-mil HDPE liner with a 200-mil synthetic drainage net leak detection system between the liner and the steel walls. Each tank is covered with an Alumadome roof. The roof of each tank is equipped with one 10-inch diameter vent, on 8-inch diameter gage port, and one hatch 24 inches square. Stairs welded to the walls of the tanks provide access to a deck at the top of the steel walls of the tanks. The hatch in each tank roof is located approximately 4 feet from the deck.

The synthetic liners in Tanks 101 and 103 are assumed to be intact, since no leakage has been detected in the leak detection system. The liner in Tank 102 appears to have been damaged, due to the presence of Basin F liquid in the leak detection system. Non-destructive T-scan tests have been run on all three tanks every six months and additional testing has been run on Tank 102. The results of these tests, available from PMRMA, indicate that the three tanks are currently structurally sound. The tank roof is made of aluminum sheets. The strength of the roof may have been affected by contact with the corrosive vapors from the liquid in the tanks.

1.3 DOCUMENT ORGANIZATION

This Preliminary Design Analysis is organized into four sections, Section 1.0 being this introduction. Section 2.0, General Description, contains a project description, statements of purpose, authority and applicable criteria, and a summary of the economic factors influencing the design criteria. Section 3.0, Design Requirements and Provisions, provides factors considered and criteria included in the design, with relevant justifications and design calculations. Section 4.0, Specification Outline, contains a listing of the specifications to be included in the final design. In general, a design analysis contains operation and maintenance (O&M) provisions; however, this project has no components requiring an O&M section and this section has been omitted.

2.0
PART 1 - GENERAL DESCRIPTION

This section provides the general description for the design analysis for the Basin F Liquid Storage Tank 102 Decontamination Demonstration Project. It contains statements of purpose, authority, applicable criteria, a description of the project and the design basis.

2.1 PURPOSE

Pursuant to CERCLA, the Basin F liquid currently stored in three tanks and one surf ce impoundment requires disposal, and the storage facilities must be decontaminated and decommissioned. During storage, the Basin F liquid precipitated crystals and these crystals must be removed and disposed to achieve decontamination. This project will demonstrate a method of dissolving the crystals in one of the storage tanks, Tank 102. The liquid formed during dissolution will be disposed of by incineration in the Submerged Quench Incinerator (SQI) and the tank will be decontaminated and decommissioned.

2.2 AUTHORITY

The implementation of this interim response action is being conducted as part of the IRA process for the RMA in accordance with the Federal Facility Agreement and the Technical Program Plan.

2.3 APPLICABLE CRITERIA

The following is a list of data and criteria which was furnished for use in the final design.

Rocky Mountain Arsenal, Draft Final Alternatives Evaluation for Basin F Ponds and Tanks Decontamination. Task IRA-2, March 1992, Contract No. DAAA 15-88-D-0022-0001.

Document and Submittal and Distribution List.

EM 385-1-1, U.S. Army Corps of Engineers, Safety and Health requirements Manual.

Architect-Engineer (A-E) Instruction Manual, dated January 1991.

2.4 PROJECT DESCRIPTION

The purpose of this project is to demonstrate the in situ dissolution of soluble solids present in Tank 102 and subsequently to decontaminate the tank. The project will be initiated after the Basin F liquid present in the tank has been removed. The removal of Basin F liquid will be done by the operator of the SQI facility. The description of this project can be conveniently divided into two phases as follows.

2.4.1 Phase One - Tank 102 Content Heating and Crystal Dissolution

The purpose of this phase of the project is to dissolve the soluble solids present in the tank. This will be done by adding an unsaturated liquid to the tank and operating a liquid heating and closed-loop circulation system to raise the temperature of the liquid in the tank to produce dissolution. The liquid used will be water or unsaturated Basin F liquid from Pond A. Based on the results of the Alternatives Report, a maximum temperature of 60° C will be used, and complete dissolution of all soluble material present is expected to occur within one week of operation. Significant evolution of ammonia, toxic organic, and odorous vapors may occur inside the tank during the liquid heating. An emission control system will be operated during this time to create a negative pressure in the tank headspace to prevent fugitive odor emissions. The vapors withdrawn from the tank will be treated using a combination of an ammonia scrubber and a granular activated carbon (GAC) air filter. When the dissolution of the soluble solids is complete, the liquid will be transferred via truck from Tank 102 to Pond A. The second phase of the project will then be implemented.

2.4.2 Phase Two - Tank 102 Interior Decontamination

This portion of the project will include removal and packaging of insoluble solids present in Tank 102, decontamination and disposal of the tank liner material, and decontamination of the tank walls and cover. An access hole will be cut in the tank wall to allow personnel to enter the tank and remove the solids present. These solids will be dewatered in a settling

tank and then placed in drums and delivered to a storage facility at RMA. The tank liner material will then be decontaminated, removed, and disposed at a appropriate off-site disposal facility. The tank walls and roof will then be decontaminated. An emission control system will be operated during this work to maintain a flow of air into the tank through the access hole. The gas will be treated using a combination of an ammonia scrubber and a GAC air filter.

3.0
PART 2 - DESIGN REQUIREMENTS AND PROVISIONS

3.1 CIVIL/STRUCTURAL ENGINEERING

The following section provides a brief explanation of the sludge removal, liner decontamination and removal, and tank decontamination during the Basin F Liquid Storage Tank 102 Decontamination Field Demonstration Project.

3.1.1 Tank Sludge Removal

Some insoluble debris (sludge) will likely remain at the conclusion of the dissolution process. The sludge is expected to be primarily composed of fine sands and silts from the bottom of Basin F that were pumped to the tank and suspended in the Basin F liquid during the first Interim Remedial Action (IRA-1). With time, the sludge has settled out. While some solids may become suspended by the recirculation during the dissolution process, it is assumed that much of the sludge volume will remain. The actual volume of the sludge is currently unknown, but it is estimated to be 180 cubic yards.

3.1.1.1 Equipment List

Settling Tanks	ST-101,ST-102
3" Diaphragm Pump (Air Driven)	P-108

3.1.1.2 Design Objective

The objective of this design is to remove the sludge from the tank, transfer it to the settling tank, and remove any free liquid.

3.1.1.3 Design Criteria

- Sludge removal will begin after the crystal dissolution is complete and all pumpable dissolution fluid has been removed.

- The sludge is estimated to be 12 inches deep with a volume of 180 cubic yards.

- All entries into the tank are confined space entries as defined in the proposed 29 CFR 1910.146 by the Occupational Health and Safety Administration (OSHA) or the final rule when promulgated.

- Lighting must be provided during all work activities.

- Tank venting and air treatment will be required during the entire sludge removal operation.

- The sludge will be removed using skid steer loaders.

- The sludge will be placed in drums, provided by the Contracting Officer (CO) and delivered to Building 785. Building 785 is the receiving area for on-site storage for PMRMA and is operated by a subcontractor. The subcontractor requires 24 hour advance notification of deliveries. Building 785 is located on the southeast corner of 7th Avenue and "E" Street.

3.1.1.4 Procedure

Grading for Staging Area

Using skid steers or similar low ground pressure equipment, the area between the northeast quadrant of the tank and the north and east berms will be graded as shown in the Drawings. At the west and south limits of grading, 1 foot high berms will be graded to run between the tank and the existing secondary containment berms. At no location will the existing surface be lowered by more than 6 inches, to protect the existing 100 mil secondary containment area.

100 mil HDPE Containment Pad

In the graded area, 100-mil HDPE liner will be placed. The liner will be laid up the side of the tank and the existing berms, 1 foot vertically. The liner will be laid across the 1-foot high berms and will be anchored at all edges using spikes, dirt fill, or other available means. All seams will be extrusion welded to manufacturer's specifications. At the locations specified in the Drawings, 200-mil geonet will be glued to the 100-mil liner to provide walkways.

Construct Tank Access

An access hole will be cut in the tank at the northeast quadrant in the same location that was used during liner construction. First, an access ramp will be built up to the bottom of the access hole will be built using flexible base material. The slope shall be no steeper than 5:1 (horizontal to vertical). Then, three hinges and two hasps will be welded to the tank along the locations of the proposed vertical cuts. The hatch will be cut. While cutting, water will be sprayed into the cut directly behind the cutting torch in order to keep the HDPE liner and geonet from igniting.

Install Wastewater Removal System

A flexible base pad, 15 feet by 30 feet by 1 foot thick will be built as shown on the Drawings. Two settling tanks (ST-101 and ST-102) will be erected on the pad. The wastewater removal system piping will consist of 3-inch PVC piping from the settling tanks to the pump, a 3-inch diaphragm pump, 2-inch diameter rubber suction hose from the pump to the tank for dewatering the sludge in situ, and a one-half inch suction line for dewatering drums and the containment area sump.

Install Lighting System

A manlift will be used to run the power cables through the access hatch in the roof and to suspend them from the roof supports. The lights will also be suspended from the roof supports. The system will be watertight.

Sludge Handling System

The sludge handling system will consist of a hopper (6 feet long by 1.5 feet deep by 3 feet wide) fabricated from steel plate. The bottom of the hopper will be sloped to a 6-inch diameter hole in the center. A chute will be fabricated from steel pipe to transfer the sludge from the hopper to the drum loading area on the outside of the tank as shown on the Drawings. A concrete form vibrator will be attached to the hopper to facilitate movement of the sludge through the chute. The liner and geonet will be removed in the location of the proposed hopper prior to the installation of the hopper. The hopper will be welded t the interior wall of the tank as shown on the Drawings.

Remove Sludge

Prior to removal, the sludge will be dewatered using the 2-inch diameter suction line. Liquid will be suctioned from sump holes that have been excavated in the sludge. The sludge will then be removed using two skid steer loaders. The sludge will be loaded into drums via the hopper and chute. Once a drum is filled, workers will insert a concrete "stinger" vibrator into the sludge to settle the solids. Any free liquid on the surface will be suctioned off using the one-half inch suction line. The drum will be sealed. Then the drum will be moved to the drum storage areas shown on the Drawings using an Integrated Tool Carrier (Caterpillar IT2) with a drum grapple. Drums will be transferred from the drum storage area onto flatbed trucks, or trailers, using a hydraulic crane, for transport to Building 785. The free liquid will be transferred via truck to the RMA CERCLA water treatment facility.

Decontaminate Skid Steers

The skid steers and other equipment will be decontaminated before leaving the tank using a pressure washer. Care will be taken to remove any solids from the underside and any hard to reach places. The equipment will then be loaded onto a flatbed truck or trailer prepared with a plastic sheet in the bed to catch any drips. The equipment will be transported to the CERCLA Wastewater Treatment Facility for final decontamination. The tires, skid plate, and other pieces will be removed to allow a thorough cleaning of the equipment.

3.1.2 Tank Liner Decontamination and Removal

Tank 102 is lined with a 100-mil HDPE liner and has a 200-mil geonet between the liner and the tank wall. The liner is believed to have been compromised during the initial filling of the tank in 1988. Samples collected from the eight bleed valves that drain the annular space (the geonet) indicate that the entire annular space may contain Basin F liquid. Non-destructive testing that is performed on the tanks as part of the monitoring program indicates that some corrosion has occurred, but that the structural integrity of the tank has not been reduced. The liquid in the annular space complicates the decontamination and removal task for several reasons: the liner will have to be decontaminated on both sides; the geonet is contaminated and possibly encrusted with crystals; and the tank wall and bottom are at least partially corroded.

3.1.2.1 Design Objective

The objective of the procedure in this section is to decontaminate and remove the liner and geonet, and to decontaminate the tank wall, floor and Alumadome roof.

3.1.2.2 Design Criteria

- The quantity of 100-mil HDPE liner to be decontaminated and removed is approximately 14,700 square feet (3.7 tons).
- The quantity of 200-mil HDPE geonet to be decontaminated and removed is approximately 12,000 square feet (1.3 tons).
- The surface area of the tank roof, walls and floor is approximately 19,600 square feet.
- The volume of decontamination water generated during decontamination to be treated at the CERCLA Wastewater Treatment Facility is approximately 275,000 gallons.

- Decontaminated materials must meet the EPA Land Disposal Restrictions and any restrictions dictated by the permitted TSD facility's permit.

3.1.2.3 Procedure

Install Tank Decontamination Hot Water Supply

Settling tank ST-101 will be used as a surge tank. Approximately 5600 gallons of clean water will be transferred to ST-101 using the water supply from SQI or tank trucks. The water will be circulated through he exchanger HE-101 using pump P-101, 4-inch diameter rubber hose for suction and discharge lines, and existing valves in the heating and recirculation system. The water will be heated and recirculated until it reaches 60° C.

Install Automatic Tank Washer

The wastewater removal piping will be altered to include a suction line from the bottom outlet of ST-101 to P-114 and 3-inch flexible hose to the tank washer. The 3-inch flexible hose will be run up the stairway, through the access hatch on the roof, and to the tank washer location. A manlift will be used to suspend the hose and the tank washer from the roof supports. The tank washer will be suspended from the roof in locations and heights shown on the Drawings.

Primary Decontamination of Tank Liner and Alumadome Roof

Using the manlift, the liner will be slit in 3-foot long horizontal cuts every 10 feet on center and the slits pulled out to allow water from the tank washer to wash the outside of the liner and geonet. The liner will also be cut around the perimeter along the bottom to allow the decontamination liquid behind the liner drain out. Before operating the washer, a sheet of HDPE will be extrusion welded to the liner across the access hatch and the hatch closed for the cleaning operation. The tank liner and roof will be washed using 5600 gallons at each of three locations shown on the Drawings. This is the only wash the roof will receive. At the conclusion of the cleaning, the water will be removed from the tank. The water will be pushed to a low spot and removed using the suction line. The water will be transferred to the settling tanks and allowed to settle for six hours. After that time, the supernate will be

pumped to a tank truck for transfer to the CERCLA Wastewater Treatment Facility and any sediments that have settled out will be drummed.

Removal and Final Decontamination of the Liner

The liner will be cut down and into manageable (3'6" square) pieces using the manlift and hook-blades. After the pieces are cut, they will be laid on the floor and washed using a pressure washer (4000-5000 psi, 60-80°C, and 3-5 gpm). Each side should be washed for 1 to 2 minutes or until all visible contamination is removed. The liner will then be squeegeed until it is near dry, removed from the tank, placed on pallets and bundled using nylon straps.

Wastewater will be handled in the same manner as during other activities.

Removal and Final Decontamination of the Geonet

These work activities will be the same as for the liner.

Decontaminate Tank Wall and Floor

Using a pressure washer (8000-10000 psi, 60-80°C, and 3-4 gpm) and a manlift, wash the tank wall starting at top and working around the tank and then down. Care shall be taken not to contaminate any surface which has already been cleaned, including the roof. Workers using spray wands will position the bucket on the manlift and the wand in such a manner as to minimize sprayback on themselves.

Decontaminate Appurtenances

All valves that are not connected to SQI piping, all blind flanges, and any other fittings or appurtenances will be removed, decontaminated using the pressure washer and replaced.

Decontaminate Equipment

All equipment that has been in contact with wastewater, sediments, or other contaminated items will be grossly decontaminated in the tank using the pressure washer. Items to be

decontaminated include: the tank washer and hoses; manlifts; pressure washer hoses and wands; any small tools used during liner removal; and the lighting and power cords. On the equipment, all removable plates and covers will be removed to allow any contamination to be cleaned. The equipment will then be transported to the CERCLA Wastewater Treatment Facility using flatbeds or trailers prepared with plastic lined beds to contain any contaminated runoff. The equipment will then be thoroughly decontaminated in the CERCLA decontamination bay.

Demobilize

Demobilization will include removing and transporting to storage any equipment owned by the Army; removing and drumming the flexible base used for pads; removing, decontaminating and drumming the 100-mil liner used for the containment area; regrading the containment area to existing; and seeding the area with natural grass.

3.1.3 Contaminated Soil Removal

Any soils contaminated during this work will be removed immediately. The soils will be removed to six inches beyond visible contamination or to the secondary containment geomembrane. The soils will be placed in drums and transported to a designated on-site warehouse. Work will be performed in a manner which minimizes the possibility of soil contamination. All work with a high risk of spillage shall have secondary containment in the form of a geomembrane with the edges raised to contain a spill or other suitable method. The Contractor is responsible for the cost of removing any soils contaminated by his/her operation.

No soil sampling or existing soil removal is proposed under this design.

3.2 MECHANICAL ENGINEERING

The following section provides a brief explanation of the mechanical systems and equipment necessary for the Basin F Liquid Storage Tank 102 Decontamination Field Demonstration Project. The section has been divided by the mechanical system/equipment function into two parts: liquid heating and recirculation system; and emission control system. A

mechanical equipment list is provided for each of these systems. Each system is described by a Design Objective, Design Criteria, and referenced design calculations.

3.2.1 Liquid Heading and Recirculation System

3.2.1.1 Equipment List

H-101	Heater Package
HE-101 & HE-102	Heat Exchangers
P-101 & P-102	Tank Fluid Pumps

3.2.1.2 Design Objective

The design objective of the equipment listed in Section 3.2.1.1 is to remove unsaturated liquid from Tank 102, heat this liquid in an external heat exchange system, and re-inject the liquid into Tank 102 for the purpose of dissolving the crystals present in the bottom of Tank 102.

3.2.1.3 Design Criteria

The system design is based on the following:

- Crystal dissolution will be initiated following removal of all pumpable liquid from Tank 102 by SQI operations. Liquid will be removed using SQI system piping connected to one of two 6-inch bottom nozzles on Tank 102.

- A maximum volume of 470 cubic yards of crystals must be dissolved based on results of field measurements presented in the Alternatives Evaluation Report. This assumes that salt crystals make up the total estimated volume of solids in tank.

- The maximum volume of liquid generated during dissolution of salt crystals

will be approximately 150,000 gallons based on results of crystals dissolution tests presented in the Alternatives Evaluation Report.

- The maximum liquid temperature in Tank 102 for dissolution of crystals will be 140° F based on test results presented in the Alternatives Evaluation Report.

- Liquid added to Tank 102 to dissolve crystals will be water or unsaturated Basin F liquid from Pond A. Water will be pumped by SQI operations into Tank 102 as needed. Addition of liquid will be through SQI facility piping connections to Tank 102.

- Operation of the system will be limited to 5 days maximum. The results presented in the Alternatives Evaluation Report support the assumption that this will be a sufficient period to completely dissolve crystals in the tank.

- Progress in achieving crystals dissolution will be monitored through collection of grab samples of circulating fluid and obtaining total dissolved solids and total suspended solids measurements for these samples using field instruments. Viewports will also be installed in the two manway covers to allow visual observation of crystal dissolution to the extent possible.

- Liquid will be removed from Tank 102 through the existing nozzles located on the bottom wall of the tank.

- The materials of construction for the heating and circulation system piping, pumps, valves and heat exchangers were selected to be compatible with the corrosive properties of Basin F liquid. Piping is either fiberglass reinforced plastic (FRP) or high density polyethylene (HDPE). Pump construction is FRP. Heat exchanger construction is Hastelloy. Valves are Buna-N diaphragm type.

- Liquid will be injected back into the tank through a perforated pipe extending across the diameter of the tank. This method will distribute the heated liquid

across the entire tank. The injection pipe will be inserted into the tank through new connections installed in two existing manways located on the tank wall. This will eliminate the need to penetrate the Tank 102 liner.

- A closed loop system will be used to heat and circulate the liquid including pumps, heat exchangers, and a heat system. Non-contact heat exchange will be used so that heat system will not come into contact with tank liquid. Two separate circulation/heat exchange loops will be used to allow increased control and flexibility. A single heat system, rented and mobile if available, will be used.

- The maximum design temperature for liquid in Tank 102 is 140° F. The heat exchange system design is based on a maximum exit temperature from heat exchanger of 160° F to reduce potential for off-gassing. The rate of heat input to the tank liquid will be controlled using automated controllers.

- The total heat exchange capacity for the system is based on heating a maximum volume of liquid of 150,000 gallons from an assumed minimum ambient temperature for early Fall operation of 40° F to a maximum final temperature of 140° F within 30 hours. The required heat load for this design basis was calculated to be approximately 6,000,000 BTU/hr.

- At the conclusion of crystal dissolution, all pumpable liquid will be transferred from Tank 102 to Pond A. Transfer will be accomplished using tank trucks.

3.2.1.4 <u>Liquid Heating and Circulation System Design</u>

The Drawings and Specifications for the project design are submitted concurrent with this Design Analysis Report as a separate package. Refer to Appendix A for manufacturer's information on equipment and to Appendix C for design calculations.

3.2.2 Emission Control System

3.2.2.1 Equipment List

D-101	High Capacity Ammonia Scrubber Tower
D-102	Low Capacity Ammonia Scrubber Tower
P-103	Scrubber Pump for High Capacity Ammonia Scrubber Tower
P-104 & P-105	Scrubber Pumps for Low Capacity Ammonia Scrubber Tower
P-106	Chemical Feed Pump for High Capacity Ammonia Scrubber Tower
P-107	Chemical Feed Pump for Low Capacity Ammonia Scrubber Tower
BL-101	Air Blower for High Capacity System
BL-102	Air Blower for Low Capacity System
F-101	High Capacity GAC Air Filter Unit
F-102	Low Capacity GAC Air Filter Unit
TK-104	Chemical Feed Tank for Ammonia Scrubber Towers

3.2.2.2 Design Objective

The design objective of the emission control system is to prevent the release to the atmosphere of ammonia vapors, toxic organic compounds, and odors during the project implementation. These objectives include maintaining a negative pressure in the sealed Tank 102 head space during crystal dissolution through tank liquid heating and recirculation,

purging Tank 102 and maintaining an adequate inflow of air through the access port during entry of personnel for decontamination of the Tank 102 interior, and treating the air before discharge.

3.2.2.3 Design Criteria

The system design is based on the following:

- The emission control system will be operated at all times while the crystal dissolution is in progress through operation of the liquid heating and recirculation system, and during the period the access port placed in the Tank 102 wall for entry for decontamination is open, until final decontamination has been completed.

- The air will be treated to remove ammonia vapors, toxic organic compounds, and odors before discharge to the atmosphere. The treatment for ammonia will be a wet packed tower scrubber system using slightly acidic water as the absorption medium. The treatment for organic compounds and odors will be granular activated carbon (GAC) air filters.

- During the liquid heating phase, the tank will remain sealed and the exhaust volume will be sufficient to handle "off-gassing", and the estimated infiltration into the tank. This volume is about 1300 cfm. During the decontamination phase, a large access port will be provided in the tank wall for personnel and equipment entry. An in-draft must be maintained, and additionally, some cooling effect is desired. The volume to meet those conditions is estimated to be about 13000 cfm. A scrubber sized for the high volume system will not provide effective scrubbing of the lower volume due to "channeling". Methods of meeting both requirements have been analyzed with a single system but it was concluded that two separate treatment systems are required.

- The design basis for the low volume system was to maintain a negative pressure of 0.1 inch water in the tank during operation of the liquid heating and recirculation system to prevent fugitive emissions of ammonia or odors

through gaps or seams in the tank cover.

- The design basis for the high volume system was to maintain a minimum air velocity of 200 fpm through the access port to prevent release of ammonia vapors or odors through this port and to provide a limited amount of temperature reduction in the tank interior.

- The maximum concentrations of ammonia and organic compounds in the vented air were estimated from results of off-gas tests presented in the Alternatives Evaluation Report. The estimated concentrations for the low volume operation are 1.4 mg/L ammonia and 0.0001 mg/L total organic compounds. The estimated concentrations for the high volume operation are 0.14 mg/L ammonia and 0.00001 mg/L total organic compounds.

- The design basis for the ammonia scrubber systems was a minimum of 99 percent removal. The design parameters for the ammonia scrubbers were obtained from a vendor and include an air to water volume to volume ratio approximately 550:1, a liquid loading rate of approximately 6 gpm/ft^2, and a packing bed depth of 6 feet.

- The GAC air filters essentially will remove 100 percent of toxic organic compounds and odors.

- The GAC air filters will be standard rented units obtained from a supplier. This supplier must have the necessary facilities and permits to regenerate the spent GAC after use. The RCRA waste list codes for the spent GAC are: F001, F002, F003, F039, K033, K097, P051, P071, U130.

- The blowdown water generated from operation of the ammonia scrubbers will be transferred using a tank truck to Pond A or the RMA CERCLA treatment facility. This water would be treated in the RMA CERCLA water treatment facility if possible; however, the high dissolved salt content may prevent this. However, the small total quantity of blowdown anticipated, less than 1500 gpd, may allow dilution with decontamination water before delivery to the

CERCLA facility.

3.2.2.4 Emission Control System Design

The Drawings and Specifications for the project design are submitted concurrent with this Design Analysis Report as a separate package. Refer to Appendix A for manufacturer's information on equipment and to Appendix C for design calculations.

3.3 ELECTRICAL ENGINEERING

The following section provides a brief explanation of the electrical systems and equipment necessary for the Basin F Liquid Storage Tank 102 Decontamination Field Demonstration project.

3.3.1 Exterior Electrical

There are three existing 25 kVA, 13.8 kV-480V transformers feeding the existing installation. These will be replaced by three 100 kVA, 13.8 kV-480V transformers and the fusible disconnect switches will be upgraded to 15A fuses.

The existing electrical switchrack, breakers,15 kVA transformer and distribution panel will be supplemented by new breakers and distribution terminal block to feed the new process equipment.

The existing site lighting will continue to be used with the contractor supplying portable, self-powered lighting equipment, if required, for night-time operation of the process equipment.

Aboveground, heavy wall metal conduit on sleepers will be used to route cable to individual equipment skids in the process area. Underground heavy wall PVC will be used to route cable to the DeCon trailer.

A leased 45 kW, 480V, 3 phase, portable generator will supply power to operate Scrubber D-102 through a manual transfer switch in the event of loss of power. The transfer of power

will occur in 5 minutes or less.

Grounding will be accomplished via 10 foot long, 3/4-inch diameter copper-clad ground rods at the switchracks (existing) and DeCon trailer (new). A grid consisting of 10 foot long, 3/4-inch diameter copper-clad ground rods and #4/0 Soft Drawn Bare Copper Cable will be located outside of the bermed area to prevent damage to the containment liner. The equipment skids will be grounded to the grid in accordance with NFPA 70.

The complete exterior system shall include the following material and equipment.

3.3.2 Transformers

The three existing 25 kVA, 13.8 kV-480V single phase distribution transformers will be replaced by three 100 kVA, 13.8 kV-480V single phase distribution transformers.

The DeCon trailer will be fed from a 15 kVA, 480V-240/120V single phase dry type transformer located at the trailer.

3.3.3 Aerial Line Conductor

No changes will be made to the existing three conductor, #2 AWG ACSR overhead line.

3.3.4 Secondary Conductors

Secondary conductors will be based on copper sized per NFPA70, using 75°C type THW or THWN 600V insulation. The color of the insulation of the ungrounded conductors of different voltage systems shall be as follows:

120/208 volt, 3-phase: red, black, and blue;
277/480 volt, 3-phase: yellow, brown, and orange;
120/240 volt, single phase: red and black.

3.3.5 Motor Control

Motor starters will be of either full voltage or reduced voltage, non-reversing type in a minimum NEMA 3R enclosure. Starters will include at a minimum: 250 VA control transformers, Hand-Off-Auto switches, manual start/stop pushbuttons and run and off lights.

3.4 CHEMICAL SAMPLING AND ANALYSIS PROVISIONS

This section describes the sampling and chemical analysis procedures to be conducted during the in situ dissolution process of Basin F crystal deposits in Tank 102 and subsequent tank interior decontamination. The discussion includes the sampling of the dissolution product, the air emissions generated during this process, and the sampling of the tank liner after decontamination for disposal in a RCRA subtitle C landfill. Samples collected for analyses off-site will be performed by an approved USACE laboratory. Methodologies to be used in the field and by the laboratory will be performed using established and recognized protocols such as USEPA Test Methods for Evaluating Solid Waste (SW-846), Third Edition, 1986, 40 CFR 60, Appendix A, and 40 CFR 61 Appendix B, American Society of Testing and Materials (ASTM) and National Institute of Occupational Safety and Health (NIOSH). All data generated for this project will be reviewed for completeness and verified in accordance with procedures and protocols specified by each method performed. All field data monitoring and sample collection will be fully documented in assigned field logbooks.

3.4.1 Crystal Dissolution

Grab samples of the dissolution product will be collected and monitored during the dissolution process as well as collecting separate grab samples for off-site testing. The field data will be used to determine the optimal dilution factor required for the SQI and to evaluate the rate of crystal dissolution. The method used for sample collection will consist of directly filling disposable plastic beakers from a sampling port from the in-line sampling port of the liquid heating and circulation system to obtain representative samples.

The results generated in the field will not require full data validation. However, each method listed below will be performed in accordance with quality assurance/quality control (QA/QC) protocols specified in each method. Each portable field instruments will also be

checked for working operation and be properly calibrated in accordance with manufacture specifications. Parameters to be monitored on-site will be as follows:

Parameter	Required Portable Instrumentation
Temperature	Thermocouple/meter
Specific Conductance	Conductivity meter and electrode
pH	pH meter and electrode
Density	Field hydrometer
Turbidity	Spectrophotometer

Duplicate grab samples and associated field QA/QC samples will be collected at the completion of the dissolution process based on field data from the in-line sampling port of the liquid heating and circulating system. Samples will be collected, preserved and containerized in accordance with each specific method listed below. The purpose of collecting and analyzing these samples by an approved USACE laboratory is for chemical characterization of the dissolution product, to monitor feed requirements necessary to optimize operations of the SQI system, and to evaluate field measurement for accuracy and precision obtained during actual field operations. The physical and chemical analysis to be performed on these samples will be as follows:

Parameter	Methodologies
GC/MS volatiles	SW-846/8240
GC/MS semivolatiles	SW-846/8270
Pesticides/PCBs	SW-846/8080
ICP metals	SW-846/3005/6010
Common Anions	SW-846/300.0
Mercury	SW-846/7470/7471
Selenium	SW-846/270.3/7741
Total kjeldahl nitrogen	SW-846/351.1/351.3
Total dissolved solids	SW-846/160.1
Total suspended solids	SW-846/160.2

Specific conductance	SW-846/120.1
Heating value (BTU)	ASTM D2382
Specific gravity	ASTM D1429

3.4.2 Emissions Control System

Air monitoring in the field and air sampling for laboratory analysis will be performed during the dissolution process. Air monitoring in the field will be performed every two hours during field operations. Air samples for laboratory analysis will be collected daily. The purpose of monitoring air emissions during fiel operations is to qualitatively characterize air emissions and to evaluate the removal of ammonia and fugitive odor emissions.

Three in-line sampling ports are available for air sampling. The first sampling port is located at the connection of the in-line air scrubbing system to Tank 102 and will be used for sampling the headspace of the dissolution product present in the tank. The second in-line sampling port is located after the in-line ammonia scrubber, and the third after the GAC scrubber. Sampling port locations are presented in the drawings.

Field monitoring will be performed every hour during operation and will consist of attaching a small air pump to the sampling port and drawing air from the tank through a glass tube specifically designed to qualitatively measure the presence of ammonia. The presence of volatile organic compounds will be measured every hour using a portable organic vapor analyzer directly at the sampling port.

Additional air samples will be collected from all three sampling ports on a daily basis and shipped to an approved USACE laboratory for analysis. The results of these analyses will be used to chemically characterize the air emissions generated during the dissolution process and to evaluate the removal efficiency of fugitive compounds by the in-line scrubber system. Parameters and methodologies to be performed will be as follows:

Parameter	Methodology	Frequency
ammonia	NIOSH 205	daily
volatile organic compounds	USEPA T0-1/SW-846/8240	daily

semi-volatile compounds	USEPA T0-4/SW-846/8270	daily

3.4.3 Tank Interior Decontamination

The Basin F sludge collected from the bottom of tank 102 will be containerized and then transferred to the RMA waste management contractor. No additional chemical analysis of the containerized sludge is anticipated.

The tank liner material subsequent to removal and decontamination will be disposed as a hazardous material. Samples of the decontamination water ᐧ 'll be collected and analyzed by an approved USACE laboratory for GCLMS volatiles, semivolatiles, pesticides/PCBs, ICAP metals and mercury.

Wastewater generated during the decontamination process of the tank liner and tank interior will be containerized and transported to the RMA CERCLA wastewater treatment facility. No additional chemical analysis of the decontamination water is anticipated.

3.5 FEDERAL, STATE, AND LOCAL ENVIRONMENTAL PROTECTION CRITERIA AND PERMITS

3.5.1 Scope

In preparation for the implementation of the RMA Tank 102 Decontamination project, a review of applicable and relevant and appropriate requirements (ARARs) was conducted. The Corps of Engineers' (COE) request for proposal (RFP) requires that all permits needed to implement the decontamination process be identified. However, CERCLA Section 121(e) exempts any response action conducted entirely on-site at a site on the National Priority List (NPL) from having to obtain a federal, state, or local permit. In general, on-site actions need comply only with the substantive aspects of Applicable and Relevant and Appropriate Requirements (ARARs), and not with the corresponding administrative requirements. Since the RMA is a site designated on the NPL and the decontamination project will be conducted on-site, permits will not be required, but all substantive requirements must be met. This section outlines those substantive requirements.

3.5.2 Applicable and Relevant and Appropriate Requirements (ARARs)

3.5.2.1 Definition of ARARs

Cleanup standards for remedial actions must attain a general standard of cleanup that assures protection of human health and the environment, is cost-effective, and uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practical. In addition, CERCLA, as amended by SARA, requires that any hazardous substance or pollutant remaining on-site meets the level or standard of control established by ARAR standards, requirements, criter ., or limitations established under any federal environmental law, or any more stringent standards, requirements, criteria, or limitations promulgated in accordance with a state environmental statute.

A requirement may be either applicable or relevant and appropriate to remedial activities at a site, but not necessarily both. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a site.

If a regulation is not applicable, it may still be relevant and appropriate. The basic considerations are whether the requirement (1) regulates or addresses problems or situations sufficiently similar to those encountered at the subject site (i.e., is relevant), and (2) is appropriate to the circumstances of the release or threatened release, such that its use is well suited to the particular site. Determining whether a requirement is relevant and appropriate is site-specific and must be based on best professional judgement. This judgement is based on a number of factors, including the characteristics of the remedial action, the hazardous substances present at the site, and the physical circumstances of the site and of the release. Compliance with all requirements found to be applicable or relevant and appropriate is mandatory under SARA.

Waivers of ARARs may be obtained under the provisions of CERCLA Section 121(d)(4) under certain circumstances. These waivers apply only to meeting ARARs with respect to remedial actions on-site; other statutory requirements, that remedies be protective of human

health and the environment, cannot be waived.

As stated above, CERCLA, as amended by SARA, requires that any hazardous substance or pollutant remaining on-site meets the level or standard of control established by applicable or relevant and appropriate regulations, standards, requirements, criteria, or limitations established under any federal environmental law, or any more stringent standards, requirements, criteria, or limitations promulgated pursuant to a state environmental statute. CERCLA Section 121(d)(2)(A) specifically limits the scope of state ARARs to standards, requirements, criteria, or limitations under environmental or facility siting laws that are promulgated and more stringent than federal requirements. The National Contingency Plan, which set forth the regulations that implement CERCLA, defines "promulgated" state requirements as state standards that are of general applicability and are legally enforceable.

"To be considered" (TBC) provisions are non-promulgated advisories, proposed rules, criteria, or guidance documents issued by the federal or state government that do not have the status of potential ARARs. However, these criteria and guidance are to be considered when determining protective cleanup levels where no ARAR exists, or where ARARs are not sufficiently protective of human health and the environment. In these circumstances, TBC values are used to establish remediation objectives.

3.5.2.2 Chemical-Specific ARARs

Chemical-specific requirements are based on health or risk-based concentration limits or discharge limitations in environmental media (i.e., soil, air) for specific hazardous chemicals. These requirements may be used to set cleanup levels for the chemicals of concern in the designated media, or to set a safe level of discharge (e.g., wastewater discharge, taking into account water quality standards) where a discharge occurs as part of the remedial activity.

Sources for potential target cleanup levels include selected standards, criteria, and guidelines that are typically considered as ARARs for remedial actions conducted under CERCLA. The chemical-specific ARARs and other criteria or guidelines to be considered are discussed below.

In general, very few cleanup standards exist for soil contamination. Often cleanup levels for non-petroleum wastes are based on a site-specific risk assessment, hazardous waste definition levels, or background levels. Recently, human health-based criteria for soil and water contaminant levels were published as guidance for RCRA Facility Investigations (EPA 530/SW-89-031, May 1989) (hereinafter referred to as the "RFI Guidance"). These standards were developed specifically for application in RCRA-related activities, although it appears they are used as proposed ARARs where no other standards exist. These guidelines are presented, therefore, as TBCs rather than chemical-specific ARARs and represent screening or "further action warranted" levels. Actual cleanup levels that may be applied to a particular area will depend on human health risk evaluations and site-specific requirements.

The RFI guidance levels are based on EPA-derived chronic exposure assumptions and are highly conservative screening levels used at RCRA facilities to determine if a more detailed health risk evaluation (a Corrective Measure Study) is warranted. As mentioned previously, they do not necessarily represent target cleanup levels.

3.5.2.3 Location-Specific ARARs

Location-specific ARARs are restrictions placed on the types of activities that may occur in particular locations. The location of a site may be an important characteristic in determining its impact on human health and the environment. The ARARs may restrict or preclude certain remedial actions or may apply only to certain portions of a site.

Threatened/Endangered Species

The objective of the Endangered Species Act (ESA) is to conserve various species of fish, wildlife, and plants that are threatened with extinction. The ESA provides for the designation of critical habitats that are "specific areas within the geographical area occupied by the species...on which are found those physical or biological features essential to the conservation of the species... ."

Section 7(a) of the ESA requires federal agencies "to ensure that the actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered or

threatened species, or adversely modify or destroy their critical habitats. Actions that might jeopardize listed species include those with direct and indirect effects, as well as the cumulative effects of other actions that are interrelated or interdependent with the proposed action" (EPA 1989).

The lead agency is required to identify whether a threatened or endangered species, or its critical habitat, will be affected by a proposed response action. If so, the agency must avoid or alter the action to ensure the species or its critical habitat are not adversely affected (EPA 1989).

Tank 102 is located outside of the RMA Bald Eagle Management Area (Figure RISR A1.6-2, Ebasco et al., May 1991) and Woodward-Clyde believes the proposed tank decontamination project will not affect any threatened or endangered species. A biological assessment may be required, however, to accurately rule out the possibility of adverse impacts to such species.

<u>Wetlands and Floodplain Management</u>

Executive Order 11990, regarding protection of wetlands, is considered applicable if remedial activities impact wetlands areas at the site. When remedial activities take place in the floodplain, Executive Order 11988, regarding protection of floodplains, is applicable. Remediation must then be conducted to avoid long- and short-term adverse impacts associated with the occupation or modification of floodplains.

The Basin F liquid storage tanks are located outside of the floodplain and are not in a wetlands area (Figures RISR A1.5-2 and RISR A1.6-1, Ebasco et al. May 1991), so floodplain and wetlands rules will not be ARARs for the decontamination project.

<u>RCRA Location Requirements - RCRA Section 3004(o)(7)</u>

RCRA contains a number of explicit limitations on where on-site storage, treatment, or disposal of hazardous waste may occur. In accordance with 40 CFR 264.18(a), new treatment, storage or disposal of hazardous waste is prohibited within 200 feet of a fault that has experienced displacement in Holocene time. Similarly, 40 CFR 264.18(b) limits the

placement of a hazardous waste treatment, storage, or disposal facility within a 100-year floodplain unless the facility was designed, constructed, operated, and maintained to avoid washouts. Finally, 40 CFR 264.18(c) prohibits the placement of non-containerized or bulk hazardous waste within salt dome formations, underground mines, and caves.

The RCRA location requirements will apply as follows to the Tank 102 decontamination project:

- 40 CFR 264.18(a) will not apply to the on-site management of hazardous wastes unless a new hazardous waste management unit is used to manage waste from the project. This section would apply to the off-site disposal of the liner and drain if they are disposed in a new unit.

- 40 CFR 264.18(b) will also not apply to the on-site management of hazardous wastes because Pond A, the submerged quench incinerator, and the on-site wastewater treatment plant are outside of the projected 100-year floodplain (Figure RISR A1.5-2, Ebasco et al. May 1991). This section would apply to the off-site disposal of the liner and drain if the disposal facility is in the floodplain.

- 40 CFR 264.18(c) will not apply to the Tank 102 project as proposed because disposal in salt dome formations and underground mines and caves is not planned.

National Historic Preservation Act (NHPA)

The objectives of the NHPA are to protect and restore areas, buildings, and objects significant to American history, engineering, architecture, or archaeology. The Tank 102 decontamination project is not expected to impact any areas, structures, or objects protected by the NHPA. The results of the RMA NHPA survey, which is still underway, must, however, be reviewed before an accurate determination may be made as to the applicability of NHPA regulations.

3.5.2.4 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative can be achieved.

Clean Air Act

National Ambient Air Quality Standards, 40 CFR 50
National Emissions Standards for Hazardous Air Pollutants, 40 CFR 61
New Source Performance Standards, 40 CFR 60

These regulations implement and set rules for a regional air pollution control program to protect the public health and welfare. These regulations are applicable if a remedial action creates air emissions regulated by these standards.

The heating system used to redissolve the solids will be a closed loop circulation system and will vent only to the tank. Tank 102 will be maintained with a negative pressure in the tank headspace and will use an emissions control system to prevent any possibility of any toxic or odorous emission during the entire Phase One and Phase Two portions of this project as described in the published specifications. The emissions control system is comprised of an ammonia scrubber and GAC filter and will be utilized continuously for the length of the project. Ammonia concentrations in the vent gas are anticipated to be in the range of 0 to 2 mg/L. Total volatile organic compound (VOC) concentrations to the GAC filters are anticipated to be in the range of 0 to 0.001 mg/L. At a removal efficiency of 99 percent or better, total VOCs emitted to the air will be less than 0.0001 mg/L. Proper disposal techniques for on-site disposal of the ammonia scrubber water and off-site regeneration of spent GAC will be conducted as required to maintain emissions within these estimated ranges.

At maximum operational flowrate and with minimal 99 percent removal efficiency, VOC emissions will not exceed 0.0005 lb/hr or 4.26 lbs per year (1300 cfm x 28.317 l/ft^3 x 0.0001

mg/L x 10^{-3} g/mg x 1/454 lb/g x 60 min/hr). Under these worst-case operational conditions, no existing federal air permitting regulations are triggered. A revised Air Pollution Emission Notification (APEN) should be filed with the State of Colorado due to the toxic status of some of the VOCs. The Air Pollution Control Division of the Colorado Department of Health would determine whether compliance with the substantive requirements associated with an air permit is applicable to the Tank 102 project.

<u>Hazardous Materials Transportation Act</u>

Hazardous Materials Transportation Regulations, 49 CFR Part 107, 171-177

These regulations apply to the transportation of hazardous materials. These regulations will be applicable to the off-site transportation of the liner and geonet drain, which will be RCRA-regulated hazardous wastes. The Hazardous Materials Regulations (HTR) specify a classification system for hazardous materials and provide requirements for packaging, transporting, and handling such materials. The HTR also detail procedures for hazard communication and incident reporting. The HTR were revised significantly on December 21, 1990 (55 <u>FR</u> 52402) and December 20, 1991 (56 <u>FR</u> 66124). The regulated community, however, has until October 1, 1993 to use the old U.S. Department of Transportation (DOT) classification scheme for most hazardous materials, including hazardous waste, and until October 1, 1996 for continued use of DOT specification packaging for domestic shipment of hazardous materials (49 CFR 171.14).

According to Ms. Ann Weiss of DOT headquarters, although the Basin F fluid is a poison B liquid, the Tank 102 liner and geonet drain should be classified as "hazardous waste, solid, not otherwise specified (NOS)." If, however, the liner or drain is judged to also be poisonous, the "poison B, solid" classification would apply.

Packaging of hazardous waste solids, NOS, must be in accordance with 49 CFR 173.510 (49 CFR 173.1300). (Note: these requirements are part of the old HTR, which most transporters are still using at this point in the regulatory transition period.) Transportation of the hazardous debris off-site must be in accordance with the RCRA regulations in 40 CFR, Parts 262 and 263 as well as with the DOT regulations. The debris will be accompanied by a properly prepared hazardous waste manifest so will not require a DOT

shipping paper [49 CFR 172.205(h)].

Resource Conservation Recovery Act

Identification and Listing of Hazardous Wastes, 40 CFR Part 261

These regulations define those solid wastes that are subject to regulation as hazardous waste under RCRA. These regulations will apply to the Tank 102 decontamination because new RCRA-regulated hazardous waste, the liner and geonet drain, which "contain" listed hazardous waste, will be generated. In addition, because the tank will be decontaminated by rinsing with water or another solvent, the rinsate will be characterized as a RCRA-listed hazardous waste due to the "mixture rule" [40 CFR 261.3(a)(2)]. Rinsate that carries a RCRA listing must be managed as hazardous waste.

Standards Applicable to Generators of Hazardous Waste, 40 CFR Part 262

These regulations set standards for the management of hazardous waste by generator. These regulations will be ARARs for the Tank 102 decontamination project because RCRA-regulated hazardous waste, the liner and geonet drain, will be generated during tank decontamination procedures. The regulations require a hazardous waste generator to have an EPA identification number; to manifest shipments of hazardous waste; to package, label, mark, and placard the shipments in accordance with DOT regulations; and to perform specified recordkeeping and reporting duties (see 40 CFR, part 262).

Standards Applicable to Transporters of Hazardous Waste, 40 CFR Part 263

These regulations establish standards that apply to person transporting hazardous waste within the U.S. These regulations will be ARARs for the off-site transportation of the tank liner and drain since the liner and drain will be RCRA-regulated hazardous waste. In addition, the DOT regulations will also apply. The RCRA regulations require hazardous waste transporters to have EPA identification numbers and comply with specified manifest and recordkeeping procedures (40 CFR 263.11 through 263.22). The regulations also detail actions which must be taken by a transporter in the event of a hazardous waste release during transportation (40 CFR 263.30 and 263.31).

Standards for Owners and Operators of Hazardous Waste Facilities, 40 CFR Part 264

These regulations establish minimum standards that define the acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose of hazardous waste. The 40 CFR, Part 264 provisions which will be ARARs at the RMA for the Tank 102 decontamination are Subparts G (Closure and Post-Closure), O (Incinerators), I (Use and Management of Containers), J (Tank Systems), and possibly Subpart N (Landfills). The landfill to which the liner and drain are sent must be in compliance with all applicable provisions of 40 CFR Part 264 or Part 265.

General Closure Requirements

RMA expects to close Tank 102 after all waste and waste residues are removed from the tank. For facilities closed without leaving waste in place, the applicable sections of 40 CFR, Part 264, Subpart G would be Sections 264.111 through 264.115. These sections contain substantive provisions including the requirements:

1. To close a facility such that the need for further maintenance is minimized [40 CFR 264.111(a)].

2. That hazards to human health and the environment are minimized [40 CFR 264.111(b)].

3. That contaminated equipment, structures, and soils are removed and properly disposed or decontaminated (40 CFR 264.114).

4. Management of all hazardous waste in accordance with the appropriate RCRA requirements (40 CFR 264.114).

Should Tank 102 be closed with waste in place, the substantive provisions of Sections 264.116 through 264.120 would apply, as would the following requirements:

1. To eliminate free liquids by removal or solidification [40 CFR 264.228(a)].

2. To stabilize remaining waste and waste residues to support cover [40 CFR 264.228(a)].

3. To install final cover to provide long-term minimization of infiltration (40 CFR 264.310).

4. To conduct thirty-year, or as specified by the EPA, post-closure care and groundwater monitoring (40 CFR 264.310).

Tank Closure Requirements

The requirements applicable to Tank 102 closure are:

- Removal or decontamination of all contaminated debris [40 CFR 264.197(a)].

- Management of contaminated debris, as appropriate, as hazardous waste [40 CFR 264.197(a)].

- If the tank is closed leaving waste in place, landfill closure and post-closure requirements (40 CFR 264.310).

Container Storage Area

The solids removed from Tank 102 will be drummed and the containers sent to a container storage area. The RCRA regulations define containers as any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled. If this type of facility is constructed, the design and operating requirements of 40 CFR Part 264 Subpart I will be addressed. The design requirements are summarized below, and the operation requirements are described below.

Design Requirements

There are two different design configurations for a container storage area: one configuration requires a containment system; the other configuration does not require this containment

configuration. The characteristics of the waste that is to be stored in the facility dictate which design configuration is selected.

A container storage area is not required to have a containment system if the following two conditions are met:

- The waste (other than F-listed dioxin wastes) contains no free liquids.

- The area is designed and operated to drain and remove precipitation, or the containers are protected from contact with accumulated precipitation.

Free liquids are defined in the regulations as any liquids which readily separate from the solid portion of a waste under ambient temperature and pressure. The paint filter liquids test, as outlined in "Test Methods for Evaluated Solid Waste, Physical/Chemical Methods," EPA Publications SW-846, is the method used to evaluate whether free liquids are present.

If the above two conditions cannot be met, the following design requirements must be incorporated into the container storage facility.

- The container storage areas must have a containment system that can contain 10 percent of the volume of containers or the volume of the largest container, whichever is greater.

- This containment system must have a base sufficiently impervious to contain leaks and spills until the release is detected and removed.

- The containment system must be designed and operated to drain and remove liquids, or the container must be protected form contact with liquids.

- The containment system must be designed to prevent run-on or to contain run-on.

Two additional requirements that must be included into both design configurations are listed below:

- Containers holding ignitable or reactive waste must be at least 50 feet from the facility's property line.

- Hazardous waste containers must be separated from units storing substances incompatible with the waste, using berms, dikes, walls, or other devices (40 CFR, Part 264, Subpart I).

Operating Requirements

If a container storage area is used to manage Tank 102 sludge, the following operating standards must be addressed:

- The containers holding hazardous waste must be in good condition (without rusting or structural defects).

- The container and its liner must be constructed of materials that are compatible with the types of waste being stored.

- Containers holding hazardous waste must always be closed during storage, except when waste is being removed from or added to the container.

- The container storage area must be inspected weekly. The inspections should be developed to identify the following conditions: leaking or deteriorating containers, or a deteriorating leak detection system (40 CFR, Part 264, Subpart I).

Regulations Governing Rinsate Management

RMA plans to send the Tank 102 decontamination rinsate to an on-site wastewater treatment plant. When generated, the rinsate will be a listed RCRA hazardous waste due to the mixture rule [40 CFR 261.3(a)(2)], so certain RCRA regulations will be applicable

to management of the rinsate. Facilities which meet the 40 CFR 260.10 definition of a wastewater treatment unit are excluded from the requirements of 40 CFR, Parts 264 and 265. The wastewater treatment unit exemption only applies to the unit, and to waste while it is in the unit. The exemption does not follow the waste, so treatment or storage of a hazardous waste before or after it is in the unit would require compliance with 40 CFR, Part 264 or Part 265, as appropriate, as would disposal of such a waste after it exits a wastewater treatment unit (EPA letter from Kenneth Gray to Brenner Munger; April 1, 1985). Wastes from the wastewater treatment unit at RMA may be hazardous wastes subject to relevant RCRA regulations, once they leave the unit.

Regulations Governing Dissolution Liquid Management

The two options being considered for management of the Tank 102 dissolution liquid are to store the liquid in Pond A and/or to dispose of the liquid in the submerged quench incinerator (SQI). Storage of the liquid in Pond A would trigger the 40 CFR, Part 264, Subpart K requirements, which apply to surface impoundments. Hazardous waste surface impoundment requirements include the following:

1. Surface impoundments must be lined. The liner must prevent migration of wastes from the impoundment [40 CFR 264.221(a)].

2. The impoundment must be designed, constructed, and maintained such that overtopping is prevented [40 CFR 264.221(f)].

3. Impoundment dikes must be designed, constructed, and maintained such that massive failure of the dikes is prevented [40 CFR 264.221(g)].

4. During construction and operation of the pond, inspections must be conducted as specified in 40 CFR 264.226.

5. The impoundment must be removed from service if the liquid level in the pond drops suddenly and is not due to changes in pond entry or exit flows, or if the dike leaks [40 CFR 264.227(a)].

6. Incompatible wastes may not be placed in the same surface impoundment without compliance with 40 CFR 264.17(b) (40 CFR 264.230).

7. Compliance with appropriate land disposal restriction provisions, including ensuring the waste meets treatment standards before it is deposited into the impoundment (49 CFR, Part 268).

Disposal in the SQI would trigger the 40 CFR, Part 264, Subpart O incinerator requirements. Subpart O substantive requirements which could apply to the SQI include the following:

1. Analysis of the waste feed (40 CFR 264.341).

2. Achievement of performance standards for hydrogen chloride, principal organic hazardous constituents, and particulates (40 CFR 264.342 and 264.343).

3. Monitoring of parameters such as combustion temperature, waste feed rate, combustion gas velocity, and carbon monoxide [40 CFR 264.345(b)].

4. Control of fugitive emissions and use of an automatic cutoff system (40 CFR 264.345).

5. Disposal of all hazardous waste and residues, including ash, scrubber water, and scrubber sludge (40 CFR 264.351).

Treatment/Storage/Disposal Facility (TSDF) Air Emissions Rules

On June 21, 1990 (55 FR 25454), EPA promulgated regulations governing emissions from (1) process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, and air and steam stripping operations, which manage hazardous waste that contains ten parts per million by weight (ppmw) or more of total organics and (2) leaks from equipment that holds or contacts hazardous waste that contains ten percent or more by weight of total organics. The current TSDF air emissions regulations will not be

applicable to the Tank 102 project because the tank contains less than ten ppmw and less than ten percent organics and the equipment involved in the project is not covered by the TSDF air emission rule. The crystals in the tank are mainly composed of sodium sulfate and sodium chloride, and the process equipment involved in the Tank 102 project includes a heat exchanger and wet scrubber, but no equipment regulated by the June 21, 1990 rule.

Although the process vent and equipment leak rule does not apply to the Tank 102 project, proposed Phase II of the TSDF air emissions regulations (July 56 FR 33490), which will apply to air emissions from tanks, surface impoundments, containers, and miscellaneous units, could be a TBC or an ARAR for the project. EPA explains in the proposed rule that

even if the managed waste contains less than 500 ppmv (the concentration cutoff for the Phase II rule), the rule could be relevant and appropriate (56 FR 33498).

Land Disposal Restrictions and the Proposed Contaminated Debris Rule

Land Disposal Restrictions, 40 CFR 268

These regulations establish a timetable for the restriction of burial or land disposal of hazardous waste. They also establish treatment standards which must be met prior to the placement of hazardous waste in land-based units. The regulations will apply to the Tank 102 decontamination project because hazardous waste (the liner and drain) generated during the decontamination procedures will be placed in a land-based disposal unit.

The 100-mil HDPE liner and 200-mil geonet drain from RMA's Basin F storage tank (Tank 102) are contaminated with wastes including F039, multi-source leachate, and will be subject (once removed from the tank) to the current land disposal restrictions. Current land disposal restrictions for F039 wastes specify concentration-based treatment standards for a large number of contaminants [40 CFR 268.43(a)]. The liner and drain may also be subject to other treatment standards, should treatment standards for other wastes contaminating the debris be more stringent than those for F039 waste. For example, the liner and drain are also contaminated with F001, F002, F003, K033, K097, P051, P071, and U130 wastes. Such wastes may have one or more contaminants with concentration standards below the F039 standard.

The treatment standards for organics in F039 waste are mainly based upon incineration, and for inorganics on stabilization (54 FR 48464). The national capacity variance for debris contaminated with waste that has treatment standards based on incineration and other specified treatment methods had applied to F039 wastes (EPA letter from Sylvia Lowrance to Douglas MacMillan; July 31, 1990), but expired on May 8, 1992. On May 8, 1992, EPA signed a rule granting a further capacity variance of one additional year to hazardous debris (debris contaminated with listed waste or which exhibits a hazardous characteristic) except for debris contaminated with listed solvents or dioxins or with California-list non-liquids (57 FR 20770; May 15, 1992).

According to Debbie Wood of EPA Headquarters, the new extension, to May 8, 1993, does not apply to F039 debris if the debris is also contaminated with listed solvents or dioxins; therefore, according to Ms. Wood, the RMA tank liner and drain would be currently subject to land disposal restrictions. The preamble to the Third rule, however, discusses F039 waste and states "when today's rule is effective, a generator does not have the option to continue classifying their multi-source leachate (under the waste code carry-through) as all the listed wastes from which it is derived; multi-source leachate must be classified as F039" (55 FR 22619; June 1, 1990). The regulations do not specify whether waste contaminated with F039 as well as listed solvents is covered under the variance, but in a Federal Register preamble (54 FR 8265; February 27, 1989), EPA states "it does not appear...that the statute is so explicit on the question of whether multi-source leachate not directly attributable to disposal of a particular spent solvent is necessarily to be classified as a spent solvent for purposes of the solvent prohibition date." It is WCC's opinion that the liner and drain would carry the F039 waste code as well as the other waste codes listed above since RMA records indicate that wastes other than leachate were disposed in Basin F. The liner and drain, therefore, would not be covered under the May 15, 1992 land disposal restrictions extension. In any case, RMA plans to remove the liner and drain from Tank 102 in 1993, with land disposal of the waste after May 8, 1993. If so, the liner and drain would be subject to full land disposal regulation.

On January 9, 1992, EPA proposed regulations which would govern the land disposal of debris contaminated with hazardous waste. These regulations would revise treatment standards for contaminated debris and, as proposed, are more lenient for that debris covered by the rule. For example, the January 9, 1992 rule proposes to allow debris contaminated

with listed waste to be sent to a Subtitle D landfill after treatment if it has been treated with an appropriate extraction or destruction treatment method. The deadline for the final contaminated debris LDR rule was extended by 30 days, so the final rule is due at the end of June 1992. The January 9, 1992 rule does not, however, specify alternate treatment standards for F039 debris. Should the rule be finalized as proposed, it appears that F039 debris would have to comply with the current, concentration-based, F039 treatment standards.

LDR Storage Prohibitions

Hazardous wastes restricted from land disposal may be stored at a facility only as specified in 40 CFR 268.50. At a TSDF, restricted waste may be stored for up to one year unless the implementing agency demonstrates the storage is not solely for "accumulation of such quantities of hazardous waste as are necessary to facilitate proper recovery, treatment, or disposal" [40 CFR 268.50(b)]. After one year of storage, the burden of proof is on the owner/operator of the facility to demonstrate that the storage is necessary "to facilitate proper recovery, treatment, or disposal" [40 CFR 268.50(c)]. The storage prohibitions of Sections 268.50(b) and (c) do not apply if the restricted waste meets the applicable land disposal treatment standards. For the issue of storage prohibition, it is important to determine the date on which the contaminated debris became or will become subject to land disposal restrictions. The one-year time period for the storage prohibition would begin once the waste becomes subject to 40 CFR Part 268.

LDRs and Treatment Facility Testing Requirements

Testing requirements for treatment facilities are specified in 40 CFR, Section 268.7(a), for those wastes subject to land disposal restrictions. Treatment facilities must test waste if the waste treatment standards are concentration-based.

Sampling Requirements for Hazardous Waste Landfills

A RCRA-permitted hazardous waste landfill must obtain chemical and physical data on a representative sample of a waste before the waste may be disposed at the landfill. The data may be obtained by the landfill owner/operator or provided by the waste generator. The

federal regulations do not specify tests which a disposal facility must perform on a waste before disposing of the waste. Analyzed parameters, analyses, and sampling frequency are site-specific and are detailed in the facility's Waste Analysis Plan [40 CFR 268.7(c)(2)].

REFERENCES

Ebasco Services Incorporated, Applied Environmental, Inc., CH2M Hill Datachem, Inc., R.L. Stollar and Associates. Draft Final, Remedial Investigation (RI) Summary Report, Appendix A - Environmental Setting, RI Approach, Nature and Extent of Contamination - Figures and Plates. Version 2.3, May 1991, Contract Number DAAA 15-88-D-0024.

U.S. Environmental Protection Agency (EPA). CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements. EPA/540/G-89/009. August 1989.

3.6 HEALTH AND SAFETY DESIGN ANALYSIS

3.6.1 Introduction

The work described in this implementation document involves the interim remediation of a hazardous waste site and is within the scope of part 1910.120 of title 29 of the Code of Federal Regulations (29 CFR 1910.120), "Hazardous Waste Operations and Emergency Response." This regulation requires the development and implementation of a written safety and health program for employees involved in hazardous waste operations and also requires that a site-specific safety and health plan be written to address the hazards of each phase of the site operation. The site-specific safety and health plan must include requirements and procedures for employee protection and responses to spills and emergencies. The safety and health plan developed for this site must also be in compliance with the current edition of the US Army Corps of Engineers "Safety and Health Requirements Manual" EM 385-1-1.

3.6.2 Contamination Characterization

Basin F liquid is an aqueous liquid containing a complicated mixture of hydrocarbons, chlorinated hydrocarbons, salts, metals, and other process intermediates, by-products, and wastes. It is known that quantities of ammonium phosphate, and later copper sulfate, were added to Basin F at different times. The total organic carbon content (as C) reported for Basin F liquid ranges from 18,000 mg/l to 23,000 mg/l. This indicates that Basin F liquid is approximately 2 percent organic carbon. The major organic species, identified in samples of Basin F liquid in 1988, was 4-nitrophenol. Historical analytical data indicate that a number of pesticides are also present in Basin F liquid, but these levels are relatively low when compared to the overall total organic content (TOC).

Basin F liquid is remarkable in the wide variety of inorganic and organic compounds contained in the liquid. Although the major metallic inorganic species are sodium and potassium, significant amounts of heavy metals, particularly copper, are also present. Analyses conducted to date do not distinguish between metals present as ionic species, metals present as amine complexes, and metals potentially present in more exotic organometallic forms.

Although a significant number of organic chemical species have been identified, many of the organic compounds present in Basin F liquid are unidentified despite the fact that the samples were analyzed for an extensive range of hazardous species including compounds referenced in U.S. Environmental Protection Agency SW-846, Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, 1988. In part, this lack of identification of Basin F liquid organic species is caused by the difficulty of analyzing individual species in the complex matrix. The highly concentrated matrix has resulted in an unavoidable increase in baseline interference and higher detection limits. In addition, based on Shell's experience, many organics may be difficult to extract using standard extraction methods, due to the formation of emulsions.

Numerous studies conducted to characterize Basin F liquid indicate that its contaminants include: alcohols, fluoride, chloride, insecticides, chlorinated organics, chlorophenylmethyl sulfone, pesticides, chlorophenylmethyl sulfoxide, phenols, dicyclopentadiene, phosphorous, p,p-DDE, p,p-DDT, sulfate, acetophenone, aldrin, isodrin, arsenic, mercury, metals,

pentachloroethane, dibromochloropropane, tetrachloroethylene, dithiane, toluene, dieldrin, trichloroethane, xylene, dimethylmethyl phosphonate (DMMP), endrin, and diisopropylmethyl phosphonate (DIMP). Table 1 list results of several past and current analyses of Basin F liquid.

Basin F liquid is also remarkably high in urea according to historical results (Table 1). In general, the presence of urea would be indicative of a reducing chemical matrix. The extremely high chemical oxidation demand (COD) results suggest that Basin F liquid is a reducing matrix.

During the first Basin F IRA it was found that Basin F liquid, while still in the basin, tended to stratify. The stratification consisted of an aqueous layer on top, then a layer of crystallized material, beneath which was a layer of slushy and highly volatile organic fluids and sludges. This distinct stratification has not been observed in the tanks or Pond A, although a crystal layer has been observed on the bottom of Pond A and the tanks.

Basin F liquid was found to contain extremely high levels of total Kjeldahl nitrogen, expressed as N, in the range of 101 to 104 grams per liter (g/l). Approximately 50 percent of this amount is attributed to ammonia or ammonium ion, while the remainder of the reported nitrogen (as N) is present as urea (Shell 1986), although traces of nitrogen in other forms, such as nitrate, are undoubtedly present. Effervescence, noticed during sampling and filtering, is likely attributable to off-gassing of saturated or loosely complexed ammonia. The high ammonia content of Basin F liquid presents numerous problems in handling, transfer, and treatment.

Basin F liquid is of neutral Ph but is electrolytically corrosive. Although the ionic strength of Basin F liquid was not determined, Basin F liquid has an ionic strength (salt content) approximately ten times that of seawater. Basin F liquid was also found to contain near-saturated levels of ionic inorganic species. It is assumed from the history of liquid disposal in the basin and other information that the primary cationic species are Na^+, K^+, Cu^{+2}, Mg^{2+}, and NH_4^+, and that the anionic species are Cl^-, F^-, SO_4^{2-} and NO^{3-}.

The high ionic strength has two major impacts on implementation of the treatment alternative. First, any further concentration of the liquid (liquid removal) will increase

salting-out of major species. Second, Basin F liquid is likely to be very corrosive because of the high salt content and the metal complexing capability of ammonia.

Personal air sampling including WPA Method T01/02/03 using Carbotrap 300 adsorbent, thermal desorption and GC/MS analysis was performed during the Basin F sampling activities in September/October 1991. Basin F liquids remained at ambient temperatures throughout the sampling activities.

The following contaminants were detected in the sample: acetone, acetonitrile, 2-butanone, trichloroethane, trichloroethene, benzene, tetrachoroethene, toluene, ethylbenzene, xylene, acetic acid. Contaminants were all detected at below ppm levels, and all were orders of magnitude lower than applicable Permissible Exposure Limits.

Freons, pentane, cyclopentane, styrene, and 2-methyl butanone were also detected during sampling. These compounds are all related to blowing styrenes. Since there is no historical evidence of these compounds in Basin F, they are presumed to be from the large pieces of styrofoam that were used for a floating bridge during field activities.

Basin F liquids were tested for volatile components in June of 1992. Samples of volatiles emitted when Basin F fluids were heated to 60° C were collected at Waterways Experiment Station. Below ppm concentrations of acetonitrile, and acetone were detected during sample analysis. Ammonia was detected at concentrations of 10 - 75 ppm.

3.6.3 Hazard Assessment and Risk Analysis

Exposure limits and properties of the contaminants identified in the Basin F liquids were reviewed and are included in Table 2. Permissible Exposure Limits promulgated by the Occupational Safety and Health Administration are listed for all compounds for which such limits have been identified. Similarly, Threshold Limit Values issued by the American Conference of Governmental Industrial Hygienists are also listed. For compounds with no identified exposure limits, D_T values were listed if available. Developed by the US Army

Medical Bioengineering Research and Development Laboratory, D_T values are conservative estimates of toxicity and may be based on very limited data.

Raoult's Law was used to preliminarily identify volatile contaminants of concern from this list of known contaminants. Based on these calculations, the following compounds were identified as a potential concern for inhalation exposure during field activities: 4-chlorophenyl methyl sulfoxide, ammonia, dimethyl methyl phosphonate, diisopropyl methyl phosphonate, dimethyl disulfide. A description of these calculations has been included in Attachment A.

The above assessment is considered a conservative as the results of the previous air sampling (Section 3.6.2), showed no significant volatile organic vapor hazard.

Ammonia and dimethyl disulfide are significant odor emitting compounds. Ammonia has been detected higher concentrations than any other contaminant during recent sampling events. As noted in Table 2, ammonia has an odor threshold of 0.3 - 40 mg/m^3, and dimethyl disulfide has an odor threshold of 0.003 -0.029 mg/m^3. The health effects of ammonia are mainly irritation of the respiratory tract and mucous membranes. It is expected that ammonia will be irritating to workers at concentrations well below their acute toxicity level. Dimethyl disulfide emitted significant odors during previous field activities involving Basin F liquids, however, no concentrations of dimethyl disulfide were detected during the most recent sampling events. Therefore, it is unknown whether this compound will be detected during this project. Due to the ability to detect ammonia and dimethyl disulfide at low concentrations, these compounds can be considered indicative of total organic vapor concentrations.

The greatest human health hazard during this project is expected to result from direct contact with Basin F liquids (i.e. skin contact or inhalation of aerosolized liquids). Not only are Basin F liquids known to be corrosive, but contaminants may be absorbed through the skin during contact.

The field activities for this project are outlined in section 3. A summary of the tasks is given below.

Site Preparation and Demobilization

- Set up exclusion zones, decontamination trailer

- Collection of grab samples of the dissolution product
- Set up the propane tank
- Site grading
- Placing a 100 mil HDPE liner,
- Build a ramp to the bottom of the tank access opening
- Install a wastewater removal system
- Installation of the air treatment system - nonintrusive activities
- Installation of the heating and recirculation system - nonintrusive activities
- Install tank decontamination hot water supply
- Cut a hole in the tank

Intrusive Site Preparation

- Installation of the air treatment system - cut the hole for installing the air duct
- Installation of the heating and recirculation system - open the hatch for pipe installation
- Install lighting system
- Install sludge handling system
- Install automatic tank washer

Tank Decontamination

- Dewater sludge
- Remove sludge with skid steer loaders
- Primary decontamination of tank liner and alumadome roof
- Removal and final decontamination of the liner
- Removal and final decontamination of the geonet
- Decontaminate tank wall and bottom

Equipment Decontamination

- Decontaminate skid steers
- Decontaminate equipment

During field activities, physical hazards will include standard construction hazards. These will include but are not limited to confined space entry; uneven ground; slip, trips, and falls; sensory and dexterity hazards from wearing personal protective equipment (PPE); electrical hazards; cutting and welding hazards; heat and cold stress; noise; and physical and overhead hazards involved with the use of heavy equipment, personnel hoists, and cranes, ingress and egress into bermed area near the tank.

Chemical hazards during site preparation and demobilization are expected to be limited. Exposures to Basin F liquids are not anticipated. Personnel shall wear protective equipment during these activities which will protect them from physical construction hazards.

By the time the opening in the tank is made, the air handling system will be in place. This system is designed to pull 4 air exchanges per hour. The tank will be under negative pressure. It is anticipated that all contaminated materials will be pulled into the tank away from the breathing zone of the workers. When making the cut in the tank, it is critical that water is sprayed into the cut behind the cutting torch to keep the HDPE liner and the geonet from igniting.

To connect the hot water supply system, valves on ST101, P101, and HE101 must be opened. The potential exists for very small amounts of dilute Basin F liquids to be in the piping. Personnel must don splash protection to prevent exposure during this operation.

All intrusive site preparation activities, tank decontamination and equipment decontamination activities will require potential exposure to either high concentrations of Basin F liquids or aerosolized Basin F liquids. These activities must be conducted in self contained breathing apparatus or airlines, and skin protection.

Intrusive site preparations and tank decontamination will require personnel to enter the tank through either the side opening or through the roof hatch. Due to the potential chemical exposure hazards and the physical hazards caused by the use of mechanical equipment within the tank, entry into the tank must be treated as a confined space entry. Confined space permits must be prepared prior to entry for each work shift which will identify required safety equipment and procedures. Pre-entry air monitoring must be conducted.

Heat stress will be a significant hazard during intrusive site preparations and tank decontamination. Methods for limiting heat and cold stress shall be devised and implemented. Depending on site conditions either a work rest regime or use of appropriate personal cooling devices (section 4.8.1.3.10) shall be employed to prevent heat stress during intrusive activities. In addition, adequate precautions shall be made to prevent heat stress in workers who have not been acclimatized.

During site preparation the heating and recirculation system will be installed on site. These will include a 6,000 gallon propane tank and piping which will contain oil which will be heated to 300° F. Sources of ignition must be kept away from the pr ane tank, and personnel must be notified of the hazards associated with accidental breakage of the heated oil line.

The air treatment system will include a wet scrubber which will remove ammonia from the air by precipitating it out in solution. The result will be blowdown water which will contain ammonia and some volatile organics. Personnel will be required to connect and disconnect hoses when the blowdown water is pumped from the air treatment system to tank trucks on site. No significant inhalation exposure is anticipated for this activity. Personnel will be required to don protective equipment to prevent direct skin contact with blowdown water.

Similarly, liquids from the settling tanks will be pumped from the tanks to nearby tanker trucks. Personnel must don splash protection to prevent direct skin contact while connecting and disconnecting lines.

Disconnecting lines will be a potential physical and chemical exposure hazard during this work. Personnel must assure that lines are not under pressure and are not filled with contaminated liquids before breaking lines.

Additional hazards may be encountered during this work depending on site conditions. Potential hazards must be analyzed on a task-specific basis by a competent safety and health professional.

3.6.4 Site-Specific Safety and Health Plan Preparation

The site-specific safety and health plan will be written by or under the direction of an American Board of Industrial Hygiene Certified Industrial Hygienist experienced in hazardous waste work. The plan will be signed by the responsible contractor safety and health officer and project manager at a minimum. The contractor will certify in writing to the Contracting Officer (CO) that a fully appropriate and compliant plan has been produced and will supply the CO with a copy of said plan.

A fully trained and experienced Site Safety and Health Officer (SSHO), responsible to the CIH, may be delegated to implement the Safety and Health program and site specific elements on site, with the enforcement responsibility being retained by the site Safety and Health Manager.

At least one person certified in first aid/CPR by the Red Cross or equivalent agency shall be present on-site at all times.

3.6.5 Training

Due to the potential for chemical exposure on this site, and the requirement for use of self contained breathing apparatus or airlines, all personnel must, at a minimum, have successfully completed 40 hours of OSHA training. No one may fulfill this requirement by the grandfather allowance outlined in 29 CFR 1910.120.

Site specific training covering site hazards, procedures, and all contents of the SSHP shall be conducted by the SSHO for on-site employees and visitors prior to commencement of work or entering the exclusion zone.

3.6.6 Personal Protective Equipment

Due to the risk of exposure to a matrix of compounds with unknown health effects, concentrations of ammonia, 4-chlorophenyl methyl sulfoxide, diisopropyl methyl phosphonate, dimethyl disulfide, dimethylmethyl phosphonate. Self contained breathing apparatus or airlines and skin protection must be required during all activities where there

is a potential for inhalation of high concentrations of Basin F compounds or exposure to aerosolized Basin F liquids. During non-intrusive air monitoring, non-intrusive support activities, protective equipment levels can be downgraded to skin protection only. Site preparation, and demobilization may be conducted in protective equipment for site physical hazards. The effectiveness of air purifying respirator (APR) cartridges in removing the Basin F Liquid vapors from the air is unknown. APR, therefore, shall not be utilized during field activities for this project.

Appropriate PPE Levels must be confirmed with Industrial Hygiene monitoring (Section 3.6.8.1). Exposure to hazardous materials will be kept as low as reasonably achievable and will in no case exceed the permissible exposure limits specified in 29 CFR 1910.1000. In planning for worker protection, engineering controls to protect workers must be used whenever feasible, and personal protective equipment will be used only when engineering controls are not feasible.

3.6.7 Medical Surveillance

All personnel working on this site must participate in a medical surveillance program which is overseen by a licensed physician who is certified in Occupational Medicine by the American Board of Preventative Medicine or who is Board-eligible. The medical surveillance program must fully comply with 29 CFR 1910.120 (f) and ANSI 288.2. Due to the requirement for wearing self-contained breathing apparatus and the potential for exposure to contaminants of concern, the following are minimum requirements for the medical surveillance program.

- complete physical
- pulmonary function test
- CBC differential
- SMAC 22,
- urinalysis,

3.6.8 Exposure Monitoring/Air Sampling

3.6.8.1 Industrial Hygiene Monitoring

Monitoring of the workers breathing zone must be conducted during all intrusive activities to verify employee exposures.

A FID shall be used during all intrusive activities to document employee exposures to organic vapors. The FID shall be operated continuously throughout intrusive activities. A minimum of one documented reading every 30 minutes shall be obtained from within the breathing zone of the worker with the highest potential for exposure. Between documented sampling events, the FID may be placed within the work area for continuous area monitoring.

Area monitoring with a CGI shall be conducted continuously during all intrusive activities.

Monitoring for ammonia concentrations shall be conducted as needed during field activities. Monitoring will be required when ammonia concentrations are high enough to be irritating to any personnel on site. If concentrations which exceed 50% of the PEL are detected, personnel shall examine the air treatment system for possible malfunction. If concentrations cannot be controlled, a review of health and safety procedures and monitoring requirements may be required as high ammonia concentrations may indicative of exceedances of exposure limits for other organic contaminants.

Eight hour time weighted average samples must be collected to verify employee exposures. Personnel samples must be collected during initial intrusive activities on site. If concentrations are detected which exceed 50% of the permissible exposure limit, additional sampling may be required in order to determine appropriate engineering controls or protective equipment. The following methods shall be used to document exposures to potential contaminants:

COMPOUND	SAMPLING METHODOLOGY
4-Chlorophenyl methyl sulfoxide	PMRMA* CM03
Dimethyldisulfide	OSHA IMISD651
Dimethyl methyl phosphonate	PMRMA CM03
Diisopropyl methyl phosphonate	PMRMA CM03

*These methodologies have been developed specifically for Rocky Mountain Arsenal. No NIOSH, OSHA or EPA methods are available for these compounds.

In addition, samples may be collected on a 3 stage carbon molecular sieve adsorption tube. Samples shall be analyzed by thermal desorption and mass spectrometer analysis. Some unknown contaminants may be identified by this method

3.6.8.2 Perimeter Air Monitoring

Additional perimeter air monitoring will not be needed for this project. The exhaust air will be monitored continuously throughout the project. A negative pressure will be exerted on the tank throughout the field activities, such that all exhaust air will pass through the monitoring system. In addition, ammonia and dimethyl disulfide will be detected by smell by workers in the area before concentrations of other volatiles become a concern. Detection of these compounds outside of the exclusion zone can be used as an indicator of a breakdown of the air treatment system.

3.7 DECONTAMINATION

Due to the potential for exposure to contaminants, equipment and personnel decontamination stations and shower facilities must be available on-site. All personnel who conduct work within the exclusion zone must 1) process through the decontamination zone and wash, rinse and remove contaminated PPE before entering the support zone, and 2) shower before leaving the site. At a minimum, a decontamination solution of Alconox and water will be used at wash stations within the decontamination line. Due to the potential

for exposure to highly toxic contaminants, the decontamination facilities must be completely set up prior to conducting any field operations. Personnel must practice emergency evacuations and emergency decontamination procedures before site work begins.

3.8 SITE CONTROL

Site control procedures must be established to reduce the accidental spread of hazardous substances from contaminated areas. At a minimum three work zones must be established: an exclusion zone, a contamination reduction zone and a support zone. The exclusion zone and contamination reduction zone must be set up around the active work site such that contaminated materials are not brought into the support zone nor removed from the site.

A communications system that includes a method of internal communications between field teams and the base of field operations and that includes external communications between on-site personnel and off-site personnel must be set up such that emergency situations and standard daily field decisions can be easily communicated.

A site map is provided in Figure G-7.

3.9 EMERGENCY AND FIRST AID EQUIPMENT

Due to the potential chemical and physical hazards at this site, the following emergency equipment shall, at a minimum, be immediately available on site: first aid kit, emergency eyewashes/showers, emergency use respirators, spill control materials and equipment, fire extinguishers.

3.10 EMERGENCY RESPONSE AND CONTINGENCY PLANNING

Due to the potential for exposure to hazardous materials, procedures that incorporate the requirements established in 29 CFR 1910.120(1) must be implemented at this site. As a minimum, the following subjects will be addressed: pre-emergency planning, incident reporting procedures, personnel roles/lines of authority, posted instructions/list of emergency contacts, emergency recognition and prevention, site topography/layout/prevailing winds, site evacuation procedures, emergency decontamination

and medical treatment, medical facility route map, critique and follow-up of emergency responses.

In case of a physical or chemical injury, the RMA Fire Department will be contacted for emergency medical treatment and ambulance service. The emergency medical facilities used for this work are:

AMI Presbyterian Aurora Hospital
700 Potomac (I-225 at 6th Avenue exit)
\urora, Colorado

<u>For Chemical Agent Injuries (not anticipated)</u>

Fitzsimmons Army Hospital
Building 500
West Gate
Peoria and Montview
Aurora, Colorado

3.11 LOGS, REPORTS AND RECORDKEEPING

In order to maintain an effective safety and health program on this site, it is important that logs, reports and records be well maintained. The following documentation must be kept at this site:

- logs of daily activities and site safety and health field decisions,
- documentation of air monitoring results
- incident and accidents reports and documentation of all first aid treatments which are not otherwise reportable (in compliance with EM 385-1-1 Section 2),
- record of visitors sign-in, and
- records of all regularly scheduled supervisor safety meetings and field worker safety meetings (in compliance with EM 385-1-1, Section 01.C.).

ATTACHMENT A

Raoult's law was used to calculate the potential airborne concentration of the compound found in Basin F liquids. The maximum concentration of a contaminant detected during all sampling events was used to complete the calculation.

The following assumptions were required to make this assessment:

- Basin F liquids can be approximated by water
- Both Basin F liquids and water are ideal liquids
- Raoult's law is appropriate at low concentrations

$$\textit{Mole Fraction}(x) = \frac{\frac{Mass}{MWc}}{\frac{Mass}{MWc} + \frac{1000-Mass}{MWw}}$$

Given

X_1	=	Mole fraction of the contaminant
Mass	=	grams/liter of solution of the contaminant
MW_C	=	molecular weight of the contaminant
MW_W	=	molecular weight of the water
V_C	=	vapor pressure of the contaminant at the temperature of the fluids in question
P(mmHg)	=	$(V_C)(X_1)$
P_a	=	Pressure of air in mm/Hg
$(P/Pa)(10^{-6})$	=	Concentration of the contaminant in air above the fluid surface

Example Calculation

Given

Mass	=	6.09 E-02 g chloroform/l solution
MW_C	=	119 g/mol
MW_W	=	18 g/mol
V_C	=	160 mm Hg at 20°C
P_a	=	700 mm F ,

$$X_1 = \frac{\frac{6.09E\text{-}02\ g/l}{119\ g/mol}}{\frac{6.09E\text{-}02\ g/l}{119\ g/mol} + \frac{1000\text{-}6.09E\text{-}02\ g/l}{18\ g/mol}} = 9.21\ E\text{-}0.6\ \frac{moles\ chloroform}{mole/water}$$

P	=	$(X_1)(V_C)$
	=	(9.21 E-06)(160 mm Hg)
	=	1.47 E-03 mm Hg

$(P/P_a)(10^{-6})$

$$= \frac{1.47\ E\text{-}03\ mm\ Hg}{700\ mm\ Hg}(10^6)$$

= 2.1 ppm chloroform directly above Basin F liquid at 20°C

Values for concentrations directly above the liquid were compared to the most conservative of either OSHA PELs or ACGIH TLVs (see Table 2). For compounds with no established exposure limits, concentrations were compared to D_T values where available (see Table 2). Contaminants of concern were identified as any compound with a calculated concentration at or above the exposure limit or within a factor of 100 of the exposure limit. The following

contaminants of concern were identified as follows:

- 4-chlorophenyl methyl sulfoxide
- ammonia
- dimethyl methyl phosphonate
- diisopropyl methyl phosphonate
- dimethyl disulfide

SPECIFICATIONS OUTLINE

	Bidding Schedule
01010	Summary of Work
01025	Measurement and Payment
01100	Special Clauses
01200	Warranty of Construction
01300	Submittal Descriptions
01305	Submittal Procedures
01401	Safety, Health and Emergency Response
01402	Chemical Data Management
01430	Environment Protection
01440	Contractor Quality Control
01450	Spill Control
01510	Temporary Site Utilities and Services
02073	Removal and Disposition of Materials and Appurtenances from Existing Tanks
11200	Emission Control System

11205	Ammonia Scrubber Systems
11210	Chemical Storage Tank
11215	Granular Activated Carbon Filters
11300	Heating and Recirculation System
11305	Heat Source
11310	Pumps; Heating and Circulation System
11315	Heat Exchangers
15260	Piping Insulation
15280	Equipment Insulation
15510	Process Piping
15890	Ductwork
15910	Ductwork Accessories
15980	Instrumentation
15985	Sequence of Operation
16111	Conduit
16123	Wire and Cable
16170	Grounding and Bonding

16264	Diesel - Generator Set with Auxiliaries
16461	Dry Type Transformers
16476	Circuit Breakers
16480	Motor Control

APPENDIX A
MANUFACTURER'S INFORMATION

MANUFACTURER'S INFORMATION FOR MECHANICAL EQUIPMENT FOR LIQUID HEATING AND RECIRCULATION SYSTEM

TAG Inc.

MANUFACTURER'S REPRESENTATIVES

6409 SOUTH LOCUST WAY • ENGLEWOOD, COLORADO 80111

303-771-3120 • FAX 303-779-5961

May 22, 1992

Mr. Bill Irving
Senior Engineer
Woodward-Clyde Federal Services
Stanford Place 3, Suite 612
4582 South Ulster St. Parkway
Denver, CO 80237

303-740-2635
FAX303-694-3946

Re: Rocky Mountain Arsenal
Tank Solution Heating
Fulton Quotation No. 92FTC-0010-1

Dear Bill.

Fulton Thermal Corporation is pleased to offer their quotation for your 6 million BTU heater requirements. As you requested in our meeting, **Fulton** is also offering two 3 million BTU heaters.

The **Fulton** vertical heater design will provide years of trouble free service to you. The vertical layout prevents hot spots on the 2" tubes which is common in horizontal heaters. **Fulton** provides a high temperature safety switch with interlocks on each tube of the coil for shutdown and alarm signal at the terminal strip.

Either size heater will use the FT-1000 nitrogen blanketed expansion tank. The two heater option will use one expansion tank. The circulating pump is rated at 660 gpm.

Fulton is providing the skid with heater, circulating pump and by pass line with all associated piping and expansion tank. While a stack is quoted, you will want to define your specific site requirements for final design.

Thank you for your interest in the **Fulton** heater. We look forward to working with you.

Yours truly,

Tom Gray

Tom Gray
TG/km

Fulton Thermal Corporation
P.O. Box 257
Pulaski, NY 13142

May 22, 1992
Quotation

Re: Woodward Clyde Engineers
Rocky Mountain Arsenal
Fulton Quote #92FTC-0010-1

Item 1

One (1) each Model FT-0600-C, Fulton Thermopac Liquid Phase Thermal Fluid Heater, natural gas fired, modulating burner with 4 to 1 turndown, 1,500,000 BTU/hr. minimum output, fuel train built to IRI(FIA) standards, 6,000,000 BTU/hr net output at 5400' elevation, standard controls, complete with NEMA 4 control panel, wiring, and TEFC blower motor, air filter at inlet of heater fan, burner top rain guard, stack high temperature switch for shutdown, stack and process thermocouples; and the following safety devices including:

- A. High temperature safety switch with interlocks on each tube of the coil for shutdown and alarm signal at terminal strip - Robert Shaw or equal.
- B. Heater operation interlock with circulation pump.
- C. Flow control switch on each tube of the coil for shutdown for pump and burner.- Fulton or equal.
- D. Thermal fluid temperature control - Partlow Model MIC - 2000 or equal.
- E. High system pressure switch for complete shutdown - Honeywell Model L404 or equal.
- F. Low system pressure switch for complete shutdown - Honeywell Model L404 or equal.
- G. Expansion tank low level switch for shutdown - Square D Model HG or equal.
- H. Heater outlet pressure gauge - by Fulton or equal.
- I. Heater inlet pressure gauge - by Fulton or equal.
- J. Pump supply (vacuum) gauge - by Fulton or equal.
- K. Flame safety relay - Honeywell Model 4140 or equal.
- L. Three position selector switch: off-pump on-heat on - S&S or equal.
- M. Four indicating lights: 1. Power 2. Liquid level switch. 3. Flow. 4. Heat. - Solico or equal.

Heater designed for maximum operating temperature of 350 Deg. F, flow rate 660 GPM. 460/60/3 ODP motor voltage: 120/60/1 control and 15 Hp burner motor.

Note: All heaters are manufactured to the ASME Code, Section I, inspected and certified. A certificate is issued to customer with shipment of each heater. Please verify that you comply with all local codes when selecting heaters.

All Fulton Thermal Fluid heaters are manufactured entirely at our factories in Pulaski, New York, USA.

Note: Heaters are built with no refractory bricks and minimal refractory cement to prevent overheating and cracking of thermal fluid inside the heater should a power or circulating pump failure occur.

One (1) each Circulating Pump with air cooled mechanical seal designed for 350 Deg. F.maximum operating temperature, 660 GPM, at 55 PSI, 40 hp 3500 RPM. TEFC motor, complete less motor starter.

One (1) each Deaerator cold-seal expansion tank, N2 regulator. safety valve, Model No.FT-1000-L, 264 gallon capacity, with liquid level switch. Verify capacity based on expansion rate at operating temperature. Suitable for a maximum total system fluid content of 800 gallons based on 25% expansion rate of the thermal fluid including the heater and cold seal expansion tank capacities already accounting for a total of 220 gallons.
Nitrogen supplied to expansion tank at 80 psig through customer pressure reducing valve (2000 to 80 psig).

Note: We may have to propose a different type of expansion tank, depending on the total system fluid capacity, the type of thermal fluid to be used as well as the location of the heaters and their users.

Above equipment skid-mounted including a system by-pass pipe with automatic back pressure regulating valve with 25 psig spring for 660 gpm maximum flow; Deaerator cold-seal expansion tank located at a maximum of 10 ft. from the heater's floor level.
Skid dimensions: 108"w x 108"d x 190"t, assumed inlet not higher than 128".

TOTAL PRICE F.O.B. PULASKI, N.Y....$82350.00.

Item 1 Alternate

Two (2) Model FT-0400-C, Fulton Thermopac Liquid Phase Thermal Fluid Heaters, each with natural gas fired, modulating burner with 4 to 1 turndown, 1,000,000 BTU/hr. minimum output, fuel train built to IRI(FIA) standards, 3,000,000 BTU/hr net output at 5400′ elevation, standard controls, complete with NEMA 4 control panel, wiring, and TEFC blower motor, air filter at inlet of heater fan, burner top rain guard, stack high temperature switch for shutdown, stack and process thermocouples; and the following safety devices including:

A. High temperature safety switch with interlocks on each tube of the coil for shutdown and alarm signal at terminal strip - Robert Shaw or equal.
B. Heater operation interlock with circulation pump.
C. Flow control switch on each tube of the coil for shutdown for pump and burner.- Fulton or equal.
D. Thermal fluid temperature control - Partlow Model MIC - 2000 or equal.
E. High system pressure switch for complete shutdown - Honeywell Model L404 or equal.
F. Low system pressure switch for complete shutdown - Honeywell Model L404 or equal.
G. Expansion tank low level switch for shutdown - Square D Model HG or equal.
H. Heater outlet pressure gauge - by Fulton or equal.
I. Heater inlet pressure gauge - by Fulton or equal.
J. Pump supply (vacuum) gauge - by Fulton or equal.
K. Flame safety relay - Honeywell Model 4140 or equal.
L. Three position selector switch: off-pump on-heat on - S&S or equal.
M. Four indicating lights: 1. Power 2. Liquid level switch. 3. Flow. 4. Heat. - Solico or equal.

Heater designed for maximum operating temperature of 350 Deg. F, flow rate 660 GPM. 460/60/3 ODP motor voltage: 120/60/1 control and 7.5 Hp burner motor.

Note: All heaters are manufactured to the ASME Code, Section I, inspected and certified. A certificate is issued to customer with shipment of each heater. Please verify that you comply with all local codes when selecting heaters.

All Fulton Thermal Fluid heaters are manufactured entirely at our factories in Pulaski, New York, USA.

Note: Heaters are built with no refractory bricks and minimal refractory cement to prevent overheating and cracking of thermal fluid inside the heater should a power or circulating pump failure occur.
Nitrogen supplied to expansion tank at 80 psig through customer pressure reducing valve (2000 to 80 psig).

One (1) each Circulating Pump with air cooled mechanical seal designed for 350 Deg. F.maximum operating temperature, 660 GPM, at 55 PSI, 40 hp 3500 RPM, TEFC motor, complete less motor starter.

One (1) each Deaerator cold-seal expansion tank, N2 regulator, safety valve, Model No.FT-1000-L, 264 gallon capacity, with liquid level switch. Verify capacity based on expansion rate at operating temperature. Suitable for a maximum total system fluid content of 800 gallons based on 25% expansion rate of the thermal fluid including the heater and cold seal expansion tank capacities already accounting for a total of 220 gallons.

Note: We may have to propose a different type of expansion tank, depending on the total system fluid capacity, the type of thermal fluid to be used as well as the location of the heaters and their users.

Above equipment skid-mounted including a system by-pass pipe with automatic back pressure regulating valve with 25 psig spring for 660 gpm maximum flow; Deaerator cold-seal expansion tank located at a maximum of 10 ft. from the heaters' floor level.
Skid dimensions:216"w x 86"d x 167"t, assumed inlet not higher than 105".

TOTAL PRICE F.O.B. PULASKI, N.Y....$120,060.00.

Add for the following options:

Spare circulating pump with air cooled
mechanical seal designed for 350 Deg. F. maximum operating temperature, 660 gpm, at 55 PSI, 40 Hp 3500 RPM TEFC motor, less motor starter.....$5580.00.

Skid mount second pump as spare..................$9750.00

One (1) 22" diameter x 6' high Steel Stack with 3" pipe support of stack weight to skid; includes hood and balancing barometric control; 4 wires used to hold stack are mounted to skid...................$4170.00.

Extra Instruction Manuals........................$34.00 each.

Start-up service by a factory technician is extra at $550.00 per day plus travel and accommodation expenses. Weekend and Holiday rates are extra at $825.00 per day plus expenses.

Start-up of the heater by a non-authorized Fulton Thermal Corporation engineer will void the warranty on the equipment suppplied.

Unit will be partially disassembled for shipping. Assembly required on site by others at customer's expense.

Please be aware that Fulton Thermal manufactures a custom designed product. The custom nature of our equipment necessitates incurring costs through the design, manufacture, shipment and installation process. Fulton's standard terms reflect an expenditure flow fair to both parties:

Payment Terms: 10% upon receipt of order.
20% with approval print submittal.
60% 1.5/10, Net 30 after shipment (invoice date).
10% After approved star-up or 90 days after shipment.

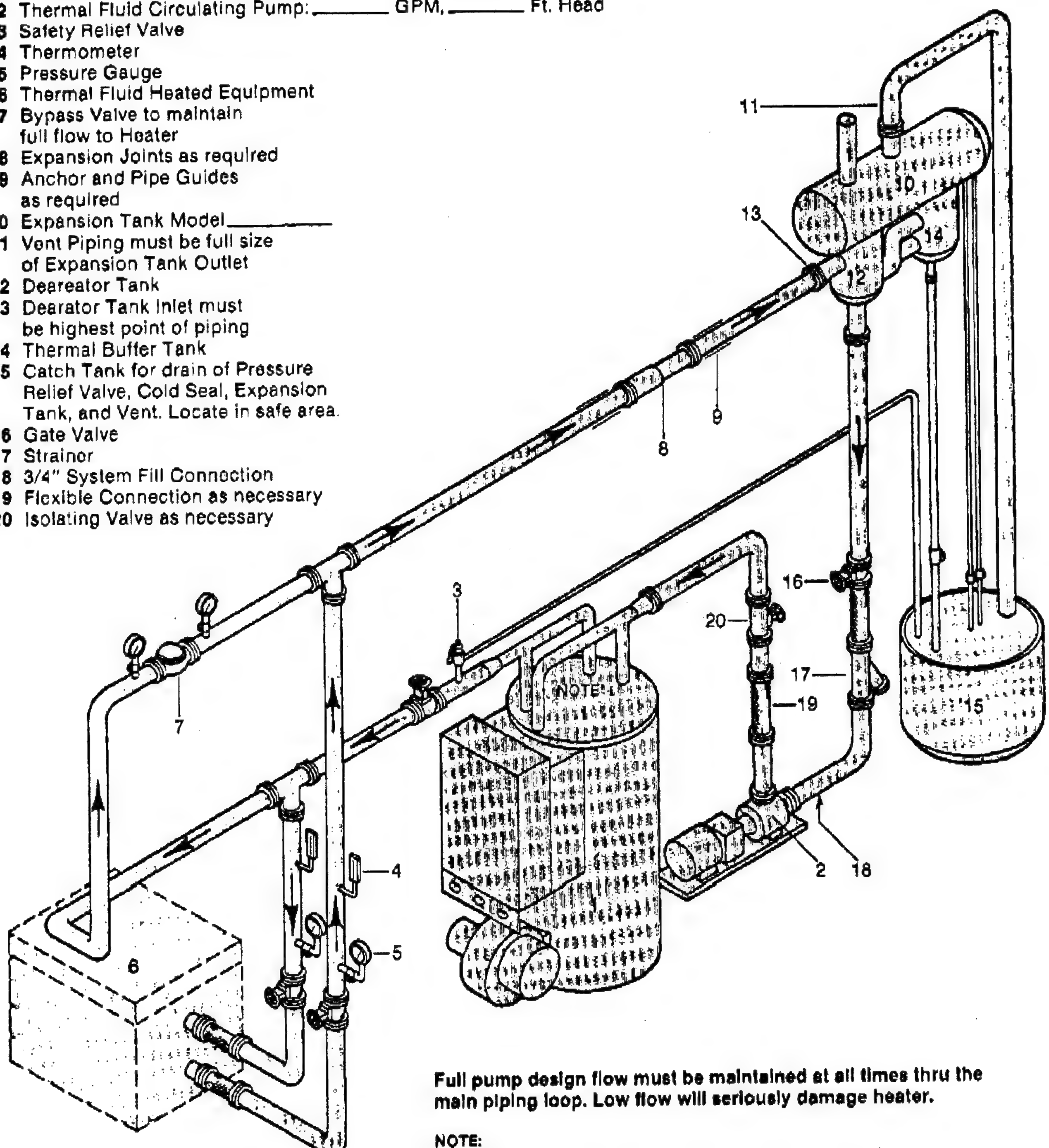
Delivery: Approval drawings 2 weeks after receipt of order and approval. Shipment 14 to 16 weeks after approval.

Fulton

Fulton Thermal Corporation

Typical Fulton Thermal Fluid Piping Schematic

1 Thermal Fluid Heater Model________; Flow Rate:______ GPM
2 Thermal Fluid Circulating Pump:______ GPM,______ Ft. Head
3 Safety Relief Valve
4 Thermometer
5 Pressure Gauge
6 Thermal Fluid Heated Equipment
7 Bypass Valve to maintain full flow to Heater
8 Expansion Joints as required
9 Anchor and Pipe Guides as required
10 Expansion Tank Model________
11 Vent Piping must be full size of Expansion Tank Outlet
12 Deareator Tank
13 Dearator Tank Inlet must be highest point of piping
14 Thermal Buffer Tank
15 Catch Tank for drain of Pressure Relief Valve, Cold Seal, Expansion Tank, and Vent. Locate in safe area.
16 Gate Valve
17 Strainer
18 3/4" System Fill Connection
19 Flexible Connection as necessary
20 Isolating Valve as necessary



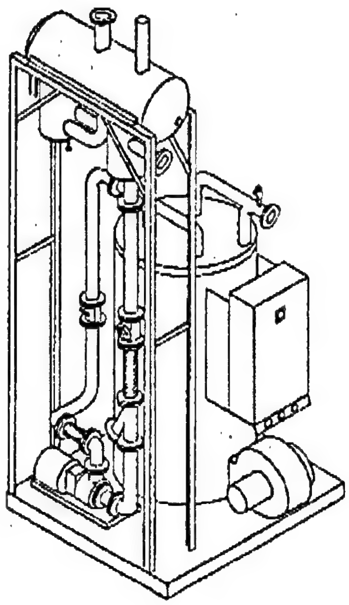
Full pump design flow must be maintained at all times thru the main piping loop. Low flow will seriously damage heater.

NOTE:
Manifold configuration for illustration only. See drawing appropriate to particular model.

TB-10-90

Fulton
Fulton Thermal Corporation

Skid Mounted and Non-Skid Mounted Fulton Thermopac



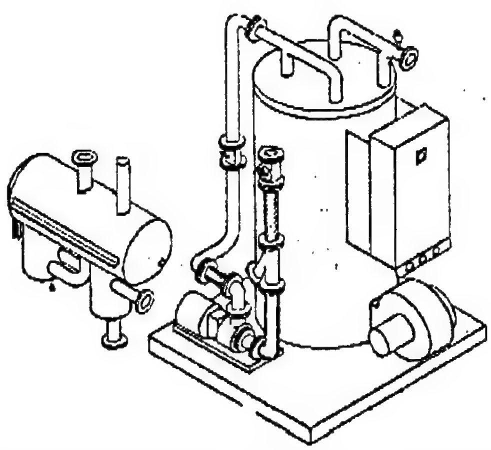
Completely Skid Mounted Units (Heater, Pump, and Tank)

Completely skid mounted units come equipped with:

A. Pipework between Deaerator Tank outlet and Pump suction including:
   1. Valve
   2. Flexible Connector
   3. Y-Type Strainer

B. Pipework between Pump discharge and Heater inlet including:
   1. Flexible Connector
   2. Valve

Note: unit will be disassembled for shipping.



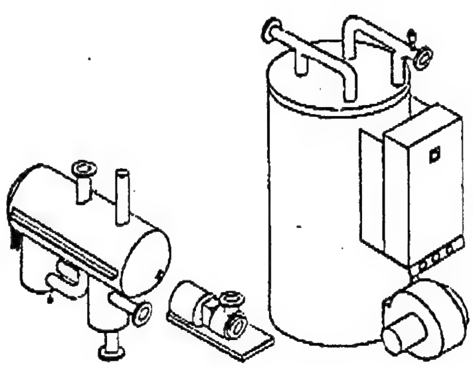
Skid Mounted Units Excluding Combination Tank (Heater and Pump)

Completely skid mounted units come equipped with:

A. Pipework between Deaerator Tank outlet and Pump suction including:
   1. Valve
   2. Flexible Connector
   3. Y-Type Strainer

B. Pipework between Pump discharge and Heater inlet including:
   1. Flexible Connector
   2. Valve

Expansion Tank is supplied separately when required.



Non-Skid Mounted Units (Heater, Pump, and Tank Without Skid Mounting)

No piping components are supplied as standard. However, they are available as options — consult factory.

Drawings are for reference only. Details may vary with model.
Specifications subject to change without notice.

Woodward-Clyde Consultants

DATE ______

PROJECT NO. ______

PAGE NO. ____ OF ____ BY ______

5/19/92 INFO from Tom Gray

Fluid is Therminol 55

Good for -15 to 550°F

Cost $8/Gallon

SP. HT. = 0.55 Btu/#°F

SP. GR = 48.5 #/cu.ft

Therm. Cond = 0.06 Btu/ft-HR-F

VISC 2.7 CP @ ~~7~~74 to 300°F

Flash Point @ 350°F

Fire Point @ 410°F

Auto Ignition @ 675°F

Pour Point @ -40°F

Heater @ 5500 Ft Elev.

	6 MBH	3 MBH
Btu input	7.65 MBH	3.825 MBH
Comb. Blower	15 HP	7½ HP
Pump	40 to 50 HP	25 to 30 HP
Foot Print	108 x 108	216" x 86"
Height	190"	167"
max. inlet height	128"	105"
PRICE	82,350	120,060 for 2

Includes

IRI Piping
NEMA 4 Electrical
Skid mounting
Bypass Piping
Altitude Rating
Rainguard
Inlet Filter
FT1000 EXP. tank for 800 Gal total System Cap
INCL. 200 gal for heater
Nitrogen Blanket
PRV
3 way valve

Not Included

Nitrogen tank w/PRV
15' Stack w/ Draft Reg. & T connection
Freight from Pulaski NY

MANUFACTURER'S INFORMATION FOR MECHANICAL EQUIPMENT FOR EMISSION CONTROL SYSTEM

BASIN F STORAGE TANK 102 DECONTAMINATION
ROCKY MOUNTAIN ARSENAL, COLORADO

CONFIRMATION NOTICE NO. _______

Woodward-Clyde Project No. 89C114MM
File No. 23016A (1.1)

Date: 6-15-92

Participants:

(To): Bill Modica/Ceilcote Air Pollution Control

(From): Joseph Scott/WCC

(Others):

Subject and Conclusion: Additional information on ammonia scrubber design.

I called to obtain additional information requested by the COE. The type of packing normally used in both scrubber designs that Ceilcote had provided is nominal 2" polypropylene Tellerettes. The air pressure loss for the SPT-24-72 tower with 24" diameter and 72" packing operated at 20 gpm and 1,300 cfm is 2" water. The air pressure loss for the SPT-72-72 tower with 72" diameter and 72" packing operated at 170 gpm and 13,000 cfm is 2" water. The sump capacity for each tower is approximately 1-1/2 minutes at liquid flow. Thus for the SPT-24-72 operated at 20 gpm the sump volume is 30 gallons and for the SPT-72-72 operated at 170 gpm the sump volume is 255 gpm.

CEILCOTE/AIR POLLUTION CONTROL
9A South Gold Dr.
Trenton, NJ 08691

Phone: 609-890-2700
Fax: 609-890-1124

FACSIMILE MESSAGE

TO: Mr. BILL IRVING
Woodward Clyde Consultants
303-694-3946

Date: 4/20/92

From: Bill Modica
National Sales Manager

Ref: Rocky Mountain Arsenal

Page 1 of 4 Pages

Bill:

Enclosed are a budget price sheet for the two ammonia scrubbing systems we discussed, as well as drawings for the two scrubbers.

As discussed, the two systems will be sized for 1400 ACFM and 13,000 ACFM. Removal efficiency for incoming ammonia gas will be 99% when using a dilute (pH 2-4) sulfuric acid solution as the scrubbing liquor.

Should you have any questions, please do not hesitate to call either me or your Ceilcote Sales Representative listed below.

cc: Tom Steinhauser
Ross Equipment Co.
Englewood, CO
303-740-9400

2" - in H_2O

CEILCOTE AMMONIA SYSTEM SIZES AND PRICES - Woodward Clyde for Rocky Mount. Arsenal Project
Airflow volume is 1400 CFM
Scrubber Model No. is SPT- 24 -72 for 99% removal
Tower is 24 inches diameter x 165 inches high (see Dwg. D-SPT-1)
Liquid recycle rate is 19 GPM
The Fybroc pump size is 1 x 1-1/2 x 6 w/2 HP, 3500 RPM Motor
FRP ductwork from outlet of scrubber to inlet of fan is included

Based on an estimated 5 inches s.p., the fan will be a Ceilcote Model CLUB-1225, operating at 3375 RPM and with a 3 HP, TEFC Motor

BUDGET PRICING

Scrubber Model SPT- 24 -72	$ 5,200
Pump Model No. 1 x 1-1/2 x 6 w/2 HP, 3500 RPM Motor	$ 2,165
PVC Recycle piping, unassembled	$ 525
pH (sulfuric acid) instrumentation and metering pumps	$ 3,500
Magnetrol liquid level controller (if desired)	$ 1,865
Ceilcote FRP Fan	$ 2,400
Interconnecting Ductwork	$ 2,200

CEILCOTE AMMONIA SYSTEM SIZES AND PRICES
Airflow volume is 13000 CFM
Scrubber Model No. is SPT- 72 -72 for 99% removal
Tower is 72 inches diameter x 203 inches high (see Dwg. D-SPT-2)
Liquid recycle rate is 170 GPM
The Fybroc pump size is 2 x 3 x 6 w/7-1/2 HP, 3500 RPM Motor
FRP Ductwork from outlet of scrubber to inlet of fan is included

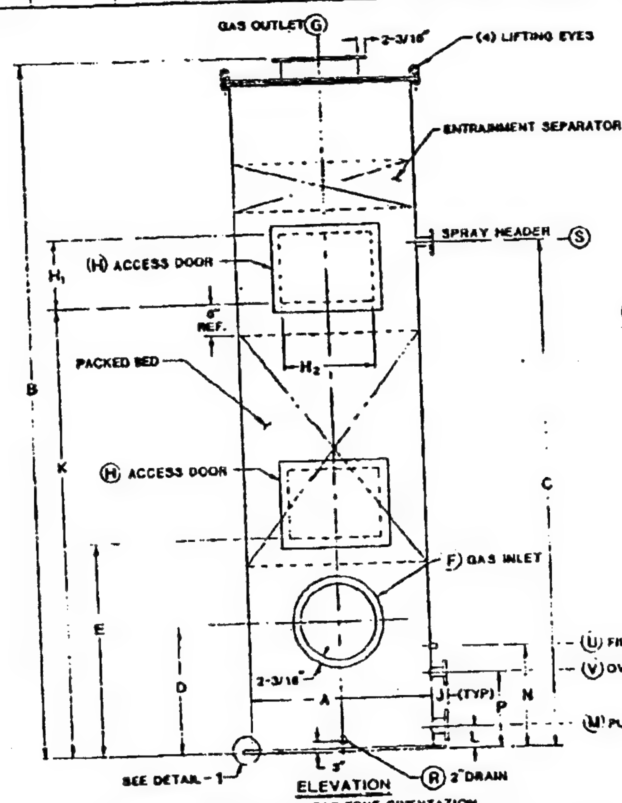
Based on an estimated 5 inches s.p., the fan will be a Ceilcote Model CLUB-3650, operating at 1010 RPM and with a 25 HP, TEFC Motor

BUDGET PRICING

Scrubber Model SPT- 72 -120	$ 19,250
Pump Model No. 2 x 3 x 6 w/7-1/2 HP, 3500 RPM Motor	$ 2,600
PVC Recycle piping, unassembled	$ 1,030
pH (sulfuric acid) instrumentation and metering pump	$ 3,500
Magnetrol liquid level controller (if desired)	$ 1,865
Ceilcote FRP Fan	$ 9,350
Interconnecting Ductwork	$ 5,800

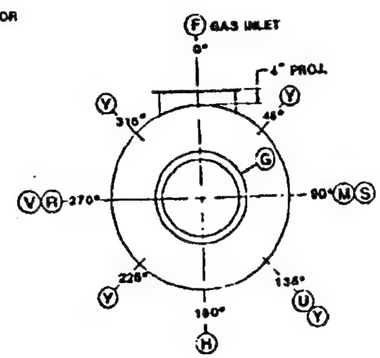
MODEL NO.	MAX. C.F.M.	PACKING DEPTH	G P M RATE@ 10 PSI	A	B	C	D	E	F	G	$H_1 x H_2$	J	K	L	M	N	P	S	U	V	Z	DRY WT. LBS.	OPERATI[NG] WT. LBS
SPT-12-36	350	36	4	12	114	85	27	42	6	6	9x9	4	77	4	1-1/2	27	20	3/4	1/2	1	21	75	170
-60		60			138	109							101									95	200
-120		120			198	169							161									145	275
SPT-18-36	1150	36	11	18	114	86	28	44	8	8	9x9	4	79	4	1-1/2	27	20	1	1/2	1	27	120	330
-60		60			138	110							103									160	390
-120		120			198	170							163									256	545
SPT-24-36	2100	36	19	24	129	96	30	48	12	12	12x12	4	83	4	1-1/2	27	20	1-1/2	1/2	1-1/2	33	190	550
-60		60			153	120							107									240	640
-120		120			213	180							187									365	865
-72	1400	72	"	"	165	132	"	"	"	"	"	"	119	"	"	"	"	"	"	"	"	275	760
SPT-30-36	3300	36	30	30	137	101	31	50	14	14	12x18	4	85	4	1-1/2	27	20	1-1/2	1/2	1-1/2	39	255	840
-60		60			161	125							109									330	975
-120		120			221	185							169									510	1300
SPT-36-36	4750	36	43	36	139	102	33	54	18	18	18x18	6	89	4	2	27	20	2	1	2	45	360	1200
-60		60			163	126							113									460	1390
-120		120			223	186							173									710	1660
SPT-42-36	6450	36	58	42	142	106	34	56	20	20	18x18	6	91	4	2	27	20	2	1	2	51	480	1620
-60		60			166	130							115									610	1870
-120		120			226	190							175									930	2490
SPT-48-36	8450	36	75	48	148	109	35	58	22	22	18x24	6	93	6	3	27	20	2	1	2	57	600	2080
-60		60			172	133							117									740	2380
-120		120			232	193							177									1080	3100

ALL TABLED DIMENSIONS ARE NOMINAL AND ARE IN INCHE[S]



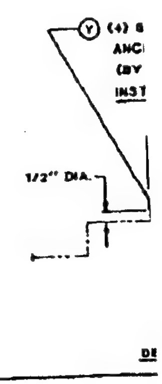
ELEVATION

SEE PLAN VIEW FOR TRUE ORIENTATION



PLAN VIEW

TRUE ORIENTATION



DE[...]

Ceilcote
Air Pollution Control

140 SHELDON RD. : BEREA, OH. 44017
(216) 243-0700 : FAX (216) 243-9854

TO: WOODWARD - CLYDE
ATTN : JOE SCOTT
303-694-3946

TOTAL NUMBER OF PAGES INCLUDING THIS COVER SHEET 3

DATE: 5-1-92

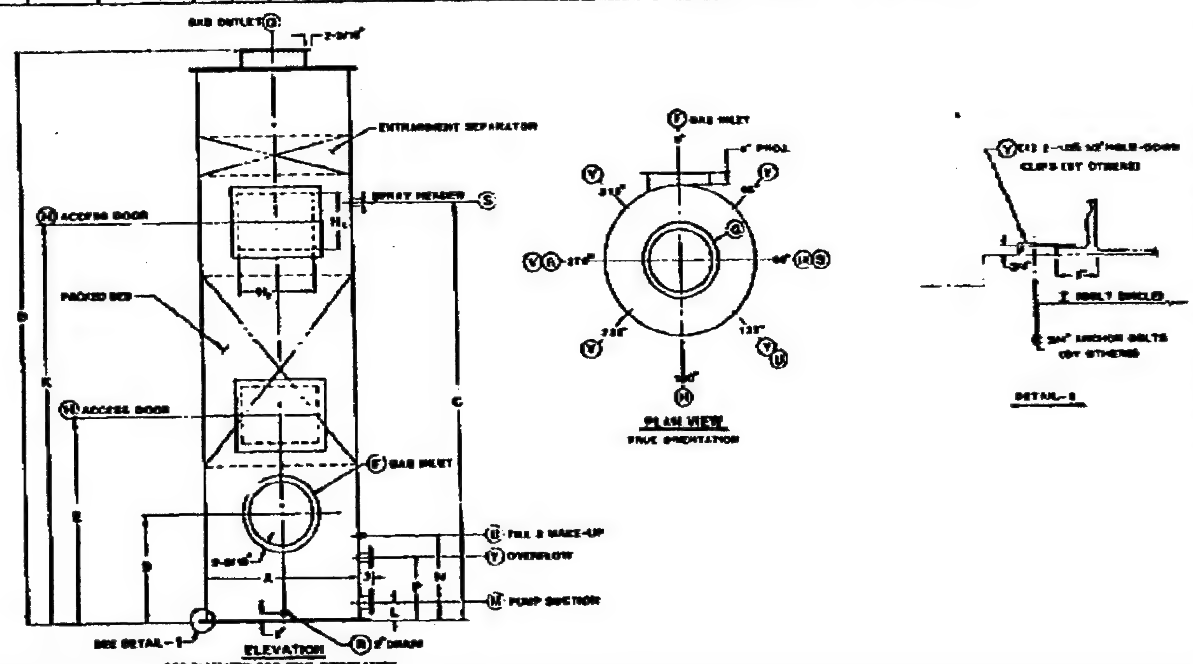
TIME SENT: 4:10 PM

IF FOR SOME REASON YOU DO NOT RECEIVE ALL PAGES, PLEASE CALL 216-243-0700 IMMEDIATELY.

CEILCOTE SENDER'S NAME: JOHN TONKEWICZ

Ceilcote
Air Pollution Control

MODEL NO.	C.F.M.	PACKING DEPTH	LIQUID RATE G.P.M.	A	B	C	D	E	F	G	H1xH2	J	K	L	M	N	P	S	U	V	Z	DRY WT. LBS.	OPERATING WT. LBS.
SPT-12-36	330	36	4	12	111	86	27	45	6	6	9x9	4	83	3	1	27	20	3/4	1/2	1	26	75	170
-60		60			135	110							107									95	200
-120		120			195	170							167									145	275
SPT-18-36	780	36	8	18	111	86	28	50	8	8	9x9	4	82	3	1	27	20	3/4	1/2	1	26	120	330
-60		60			135	110							106									180	380
-120		120			195	170							166									235	545
SPT-24-36	1550	36	18	24	127	84	28	52	10	10	12x12	4	88	3	1-1/2	27	20	1-1/2	1/2	1-1/2	32	180	550
-60		60			151	118							112									240	640
-120		120			211	178							172									385	865
SPT-24-72	1400	72			165	132							117									275	700
SPT-30-36	2500	36	30	30	137	101	31	58	14	14	12x18	6	95	3	1-1/2	27	20	1-1/2	1/2	1-1/2	38	235	640
-60		60			161	125							119									330	875
-120		120			221	185							179									510	1300
SPT-36-36	3500	36	43	36	137	101	32	61	16	16	18x18	8	95	4	2	27	20	2	1	2	44	360	1200
-60		60			161	125							119									490	1390
-120		120			221	185							179									710	1900
SPT-42-36	4900	36	58	42	140	104	33	63	18	18	18x18	8	98	4	2	27	20	2	1	2	50	480	1620
-60		60			164	128							122									610	1870
-120		120			224	188							182									830	2480
SPT-48-36	6300	36	75	48	146	108	34	65	20	20	18x24	8	102	5	3	27	20	2	1	2	56	600	2060
-60		60			170	132							126									740	2380
-120		120			230	192							186									1080	3100



NOTES:

1. UNIT MUST HAVE FULL BOTTOM SUPPORT AND SUMP MUST BE FILLED TO THE OVERFLOW BEFORE OPERATING UNIT.
2. ALL ATTACHED DUCT MUST BE INDEPENDENTLY SUPPORTED.
3. GAS INLET AND OUTLET FLANGES SHALL BE MATCH DRILLED IN THE FIELD.
4. PUMP SUCTION, SPRAY HEADER AND OVERFLOW NOZZLES ARE FLANGED; ALL OTHERS ARE THREADED CPVC COUPLINGS.
5. DESIGN PARAMETERS (MAXIMUM): TEMPERATURE: 180°F, (82°C) PRESSURE: -6" W.C. TO +12" W.C.
6. MATERIALS OF CONSTRUCTION:
   SCRUBBER SHELL- ______
   PACKING- ______
   ENTRAINMENT SEPARATOR- ______
7. SCRUBBER PAD ELEVATION CAN BE ADJUSTED TO SUIT THE HEIGHT OF THE PUMP INLET.
8. CEILCOTE WILL FURNISH 18-8 S. S. BOLTING AND FOAM NEOPRENE GASKETS FOR ACCESS DOORS AND TOP COVER UNLESS OTHERWISE SPECIFIED. ______
9. ALL TABLE DIMENSIONS ARE NOMINAL AND ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

CUSTOMER				
P. O. NO.	S. O. NO.		DATE	
PROPOSAL	MODEL		NO. REQ'D.	

OPERATING CONDITIONS				
CAPACITY		GAS IN TEMP.		
GAS IN (ACFM)		WATER VAPOR (%)		
CONTAMINANTS	INLET CONC.	OUTLET CONC.	% REMOVAL EFFICIENCY	PARTICLE SIZE REMOVED
SCRUB. LIQUID		RECYCLE RATE		
LIQUID TEMP.		RECYCLE PRESSURE		
MAKE-UP RATE		OVERFLOW RATE		
PRESSURE DROP				
REMARKS:				

THE CEILCOTE COMPANY

UNIT OF GENERAL SIGNAL CORP.

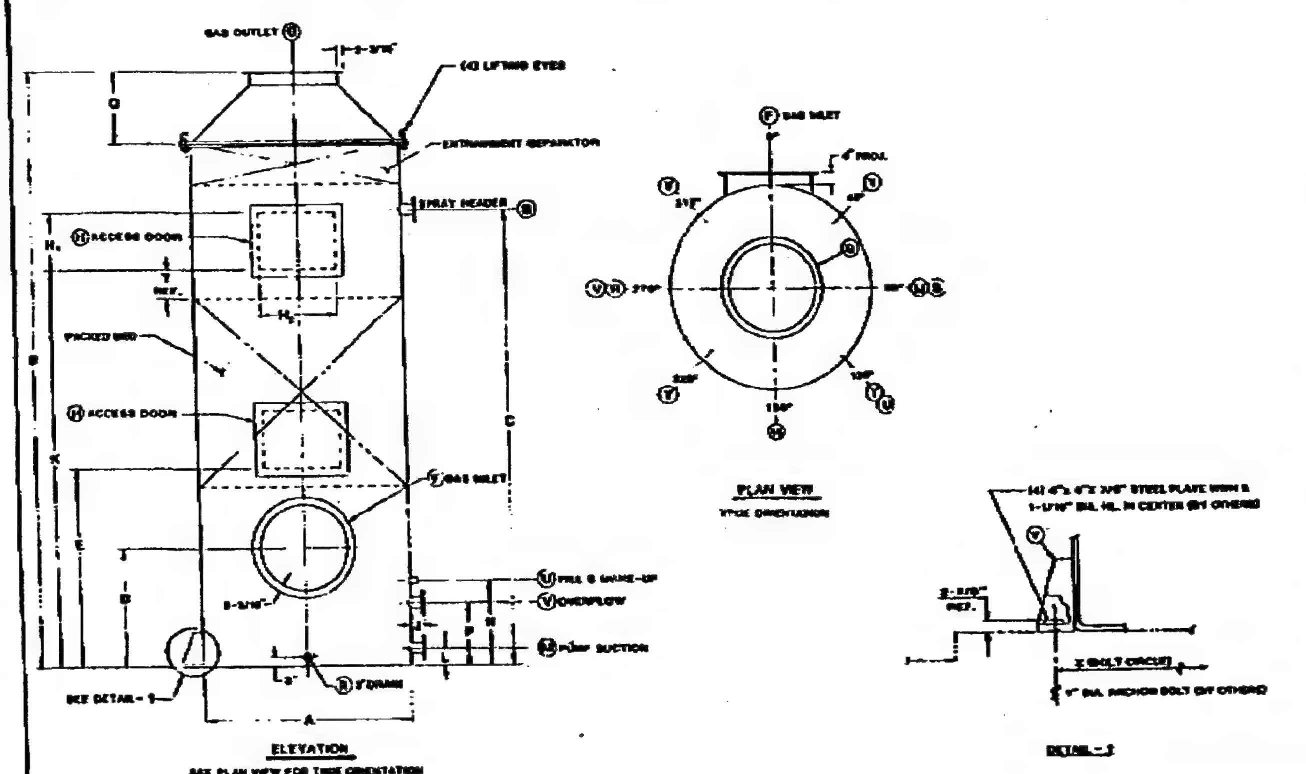
PREPARED BY:

D-SPT-1

Ceilcote Air Pollution Control

MODEL NO.	MAX. C.F.M.	PACKING DEPTH	G.P.M. RATE @ 10 PSI.	A	B	C	D	E	F	G	$H_1 \times H_2$	J	K	L	M	N	P	Q	S	T	U	V	Z	DRY WT. LBS.	OPERATING WT. LBS.
SPT-54-36	10700	36	86	54	149	116	37	62	28	28	18x24	6	80	6	3	27	20	15	3	7	1	3	62	740	2610
-60		60			173	140							122											910	2980
-120		120			233	200							183											1340	3810
SPT-60-36	13200	36	118	60	154	119	36	64	28	28	18x24	6	102	6	3	27	20	17	3	6	1	3	68	960	3280
-60		60			178	143							128											1170	3720
-120		120			238	203							186											1720	4890
SPT-66-36	16000	36	143	66	160	123	39	66	30	30	18x24	6	106	7	4	27	20	18	3	10	1-1/2	3	74	1200	4000
-60		60			184	147							130											1440	4680
-120		120			244	207							190											2100	6940
SPT-72-36	19000	36	170	72	167	129	41	70	34	34	18x24	6	112	7	4	27	20	20	3	12	1-1/2	3	SC 80	1380	4710
-60		60			191	153						6	136									3		1680	5380
-120		120			251	213							196											2440	7000
SPT-72-72		72			205	165							148											1800	6080

ALL TABLED DIMENSIONS ARE NOMINAL AND ARE IN INCHES.



NOTES:

1. UNIT MUST HAVE FULL BOTTOM SUPPORT & SUMP MUST BE FILLED TO THE OVERFLOW BEFORE OPERATING UNIT.
2. ALL ATTACHED DUCTING MUST BE INDEPENDENTLY SUPPORTED.
3. GAS INLET & OUTLET FLANGES SHALL BE MATCH DRILLED IN THE FIELD.
4. ALL FLANGES EXCEPT GAS INLET, GAS OUTLET & ACCESS DOORS ARE 150 LB. DRILLED FLANGES & ALL COUPLINGS ARE THREADED.
5. DESIGN PARAMETERS (MAXIMUM):
   TEMPERATURE: [illegible]° F ([illegible]° C)
   PRESSURE: -6" W.C. TO +12" W.C.
6. MATERIALS OF CONSTRUCTION:
   SCRUBBER SHELL- ____
   PACKING- ____
   ENTRAINMENT SEPARATOR- ____
   COUPLINGS-CPVC / 150 LB. FLANGES-CPVC
   SPRAY NOZZLE- PP ____ (NO. ____)
7. SCRUBBER PAD ELEVATION CAN BE ADJUSTED TO SUIT THE HEIGHT OF THE PUMP INLET.
8. NEOPRENE GASKETS & 18-8 S.S. BOLTING WILL BE FURNISHED FOR TOP COVER & ACCESS DOORS.
9. BOLT HLS. IN DRILLED FLANGES WILL STRADDLE NATURAL CENTERLINES.
10. SCRUBBER COLOR WILL BE GREEN UNLESS OTHERWISE SPECIFIED.
11. UNITS WITH CLIPS SPECIFIED ARE DESIGNED FOR A 100 MPH WIND LOAD.
12. THE ENTRAINMENT SEPARATOR, THE PACKING & THE SUPPORT PLATE FOR THE PACKED BED ARE SHIPPED LOOSE FOR FIELD INSTALLATION.

CUSTOMER

PROPOSAL	MODEL	NO. REQ'D.
P.O. NO.	S.O. NO.	SPEC.

OPERATING CONDITIONS

CAPACITY	GAS IN TEMP.
GAS IN (+/-IWC)	WATER VAPOR (LB/HR)

CONTAMINANTS	INLET CONC.	OUTLET CONC.	% REMOVAL EFFICIENCY	PARTICLE SIZE REMOVED

SCRUB. LIQUID	RECYCLE RATE
LIQUID TEMP.	RECYCLE PRESSURE
MAKE-UP RATE	OVERFLOW RATE
PRESSURE DROP	

REV.	DATE	DESCRIPTION	APP'D.

THE CEILCOTE COMPANY
UNIT OF GENERAL SIGNAL CORP.

DFT.	DATE	CHK.	D-SPT-2

REV. 5/87

Please reply to TYLER/Industrial
3530 W. PIMLICO AVENUE—ENGLEWOOD, COLORADO 80110
Area Code 303: 794-8112. FAX: 303-798-7434

nyb | The New York Blower Company

QUOTATION

FOB factory at LaPorte, Indiana, with no freight allowed.

Terms: 30 days net. Subject to conditions of sale on back.

This quotation, for equipment manufactured by nyb, is valid for acceptance within 15 days. Purchased components such as motors, drives and vibration bases are subject to adjustment to price in effect at time of shipment. nyb reserves the right to qualify and correct clerical errors before acceptance.

PRICE

May 8, 1992

FAX TO: Woodward-Clyde Consultants

ATTN: Joseph Scott

SUBJ: Tank venting fans

Gentlemen:

Per our discussion yesterday, we've figured fans for the two performance options you're considering. We've included an inexpensive factory applied polyurethane coating on the fan airstream for some improved resistance to the moisture present. The fan are as follows:

<u>13000 CFM</u>
1 - New York Blower Series 20 General Industrial fan, size 404DH, Arrangement 9-F, sized to exhaust 13000 CFM at 12"SP at 1227 RPM and 36.1 BHP at std. air density.

To include: 40HP 3-60-230/460V TEFC motor, v-belt drive, belt guard, shaft & bearing guard, flanged inlet and outlet, housing drain with plug, access door, and 2 mil polyurethane airstream coating for corrosion resistance.

PRICE...$5390.00

<u>1100 CFM</u>
1 - New York Blower Series 20 General Industrial fan, size 194DH, Arrangement 10, sized to exhaust 1100 CFM at 12"SP at 2437 RPM and 4.5 BHP at std. air density.

To include: 7.5HP 3-60-230/460V TEFC motor and same accessories as above.

PRICE...$1610.00

f.o.b. Laporte, IN
Terms are net 30
Shipment in 7-8 weeks.

Dimensional information attached.

Please let us know if we can help further.

Sincerely,
TYLER/industrial
Steve Tyler
Steve Tyler

ACCEPTED   THE NEW YORK BLOWER COMPANY

BY ____________________ DATE ____________ BY ____________________

Customer Name: WOODWARD-CLYDE CONS.
Tagging:TANK VENTING

File #
Date 05-07-1992

nyb | The New York Blower Company | FAN-TO-SIZE (R) July 1989 Rel 6.0 | PERFORMANCE RESULTS ----RUNTYPE 3 -----

Size 404 (100 % Width Wheel) SERIES 20 GIDH
Bare Fan - Standard Construction Materials

Operating Conditions

Density: .075 Pounds/Cu.Ft.
Temp: 70 x Fahrenheit
Altitude: 0 Ft. Above Sea Level

Point of Operation

	DESIRED	OPERATING	STANDARD
CFM:	13000	13000	13000
SP:	12	12.01	1 ..01
BHP:	36.14	36.14	36.14

Performance @ Conditions

RPM: 1227
CFM: 13000
Outlet Velocity: 4483 Ft/Min
Static Pressure: 12.01 '' WG.
Actual BHP: 36.14
Static Eff: 68 %
Mechanical Eff: 75.1 %

Notes :

Safe speed is 1639 at 70 x Fahrenheit Maximum Operating Temperature

---

Customer Name: WOODWARD-CLYDE CONS.
Tagging:TANK VENTING

File #
Date 05-07-1992

nyb | The New York Blower Company | FAN-TO-SIZE (R) July 1989 Rel 6.0 | PERFORMANCE RESULTS ----RUNTYPE 3 -----

Size 194 (100 % Width Wheel) SERIES 20 GIDH
Bare Fan - Standard Construction Materials

Operating Conditions

Density: .075 Pounds/Cu.Ft.
Temp: 70 x Fahrenheit
Altitude: 0 Ft. Above Sea Level

Point of Operation

	DESIRED	OPERATING	STANDARD
CFM:	1100	1100	1100
SP:	12	12.11	12.11
BHP:	4.49	4.49	4.49

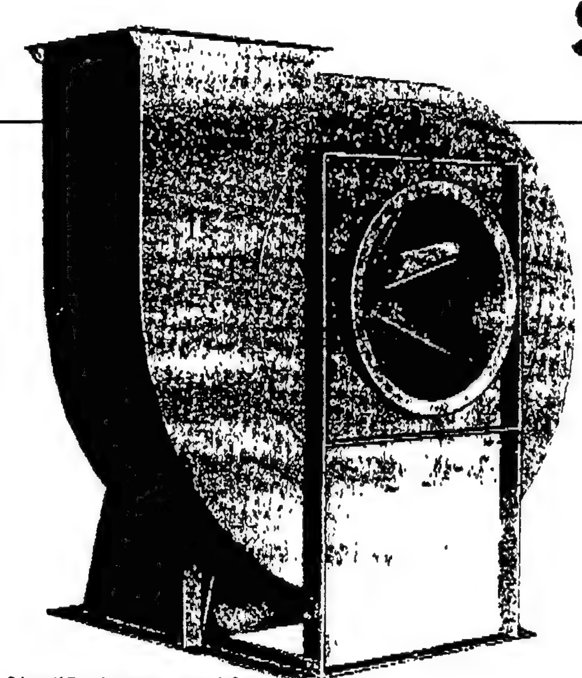
Performance @ Conditions

RPM: 2437
CFM: 1100
Outlet Velocity: 1667 Ft/Min
Static Pressure: 12.11 '' WG.
Actual BHP: 4.49
Static Eff: 46.7 %
Mechanical Eff: 47.3 %

Notes :

Safe speed is 3114 at 70 x Fahrenheit Maximum Operating Temperature

Series 20 GI Fans



Size 504 Arrangement 1
Series 20 GI Fan with
flanged inlet and flanged outlet

...for industrial air-moving and material-handling applications

This bulletin covers only Series 20 GI Fans, one of four nyb radial-blade fan lines which cover a wide range of performance and application requirements. Reference description of the other product lines appears on pages 22 and 23. The design parameters and standard features of Series 20 GI Fans are listed below.

- 14" through 85" wheel diameters
- 9" to 49" inlet diameters
- Available in a variety of packaged arrangements
- 2" to 22" static pressure
- 500 to 76,000 CFM
- Temperatures to 1000°F.

INDUSTRIAL AIR-MOVING APPLICATIONS

- Dust collection
- Combustion air
- Pneumatic conveying
- Heat recovery
- Moisture blow-off
- Incinerators
- Oven and dryer exhaust

TYPICAL USER INDUSTRIES

- Chemical industry
- Food processing
- Pulp and paper
- Pharmaceutical
- Forest products
- Primary metals
- Petrochemical
- Printing
- Woodworking

STANDARD FEATURES

Welded construction—provides rigidity for rugged industrial applications. In smaller sizes, welded housings and bases are bolted together so that housings can be unbolted and rotated to other discharge positions in the field.

Rotatable and reversible—Series 20 GI Fans with LS wheels, Sizes 144 through 364, can be rotated and reversed in the field to obtain clockwise or counterclockwise rotation and any of the available discharge positions... Series 20 GI Fans with DH wheels, Sizes 194 through 364, can be rotated to various discharge positions. DH wheels are either clockwise or counterclockwise and cannot be reversed in the field.

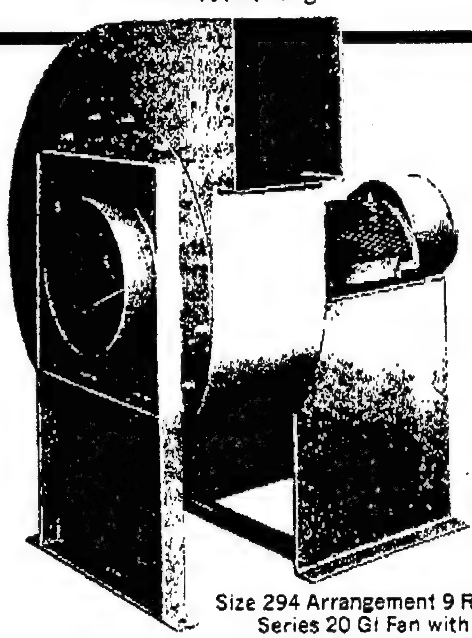
Lifting eyes—on all sizes for ease of handling.

Slip inlets and outlets—flanged connection, available as an option.

Bearings—ball or spherical roller bearings selected for extended service life over full catalog range [see page 24 for size and type].

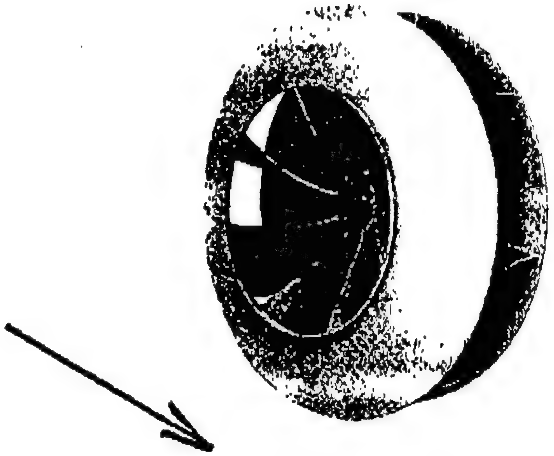
Shafting—turned, ground, and polished shafting is straightened to close tolerance to minimize "run out" and ensure smooth operation.

Precision balancing—Series 20 GI Fan wheels are dynamically balanced before final assembly. After assembly, all fans are test-run at as-ordered operating speeds.



Size 294 Arrangement 9 Right
Series 20 GI Fan with belt
and shaft and bearing guard

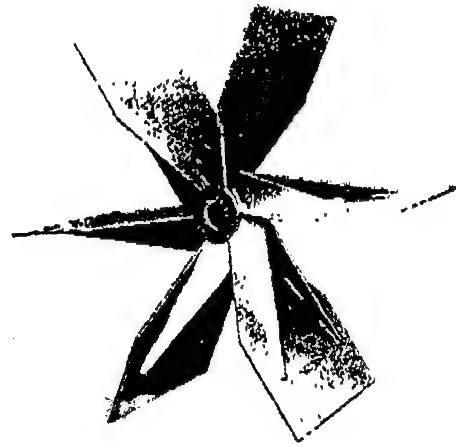
Choice of two wheel designs



DH WHEEL

Available in Sizes 194 through 854.

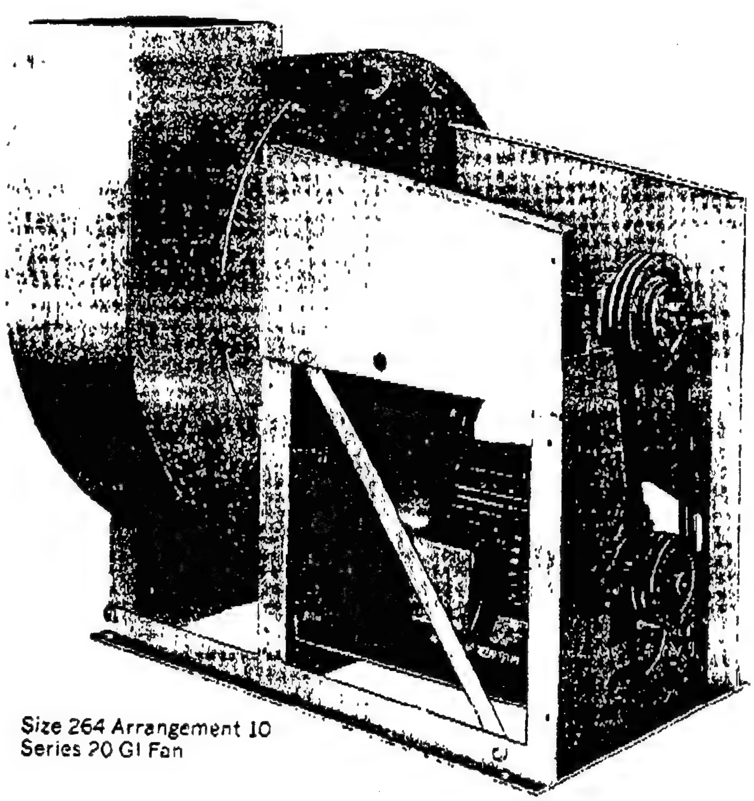
Unique, high-efficiency radial wheel utilizes curved blades and a tapered frontplate to minimize turbulence and control flow through the wheel. Can be used for airstreams with moderate dust loads that do not contain large particles or wet, sticky materials. Performance is stable from wide-open to completely closed-off.



LS WHEEL

Available in Sizes 144 through 854.

Flat radial-blade design best for material-conveying applications with airstreams containing coarse material or heavy dust and particulate matter. As with the DH wheel, the LS wheel provides stable airflow performance over the entire pressure range, from wide-open to completely closed-off.



Size 264 Arrangement 10
Series 20 GI Fan

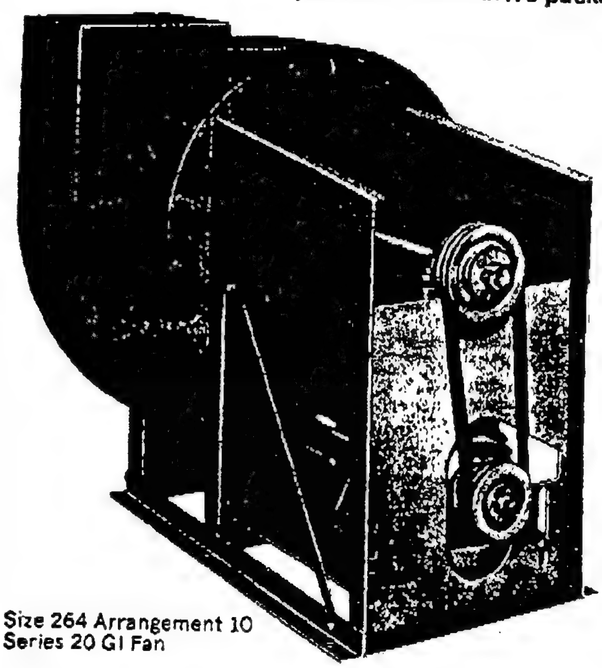
amca
CERTIFIED
RATINGS
AIR
PERFORMANCE
AIR MOVEMENT AND CONTROL ASSOCIATION, INC.

The New York Blower Company certifies that the General Industrial Fans shown herein are licensed to bear the AMCA Seal. The ratings shown are based on tests made in accordance with AMCA Standard 210 and comply with the requirements of the AMCA Certified Ratings Program.

Factory assembly of fans, motors, and drives minimizes costly field labor and allows factory test-running of the complete fan-motor-drive package.

Packaged

ARRANGEMENT 10



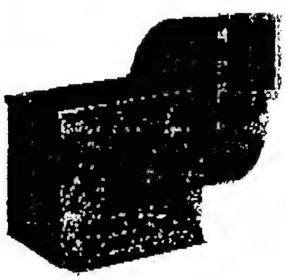
Size 264 Arrangement 10
Series 20 GI Fan

Arrangement 10 provides a compact package with good access to the motor, drive, and bearings for easy installation and maintenance.

Sizes 144 and 174 are available only with LS wheels. Sizes 194 through 364 are available with LS or DH wheels.

Maximum temperatures—standard fan: 200°F., heat fan: 600°F. Refer to page 11 for heat fan construction details.

ACCESSORIES



WEATHER COVER/ BELT GUARD

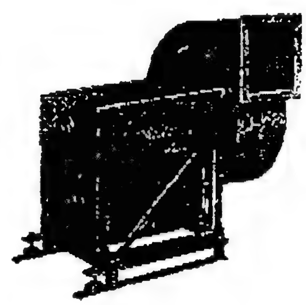
The four-piece steel assembly provides complete protection, and can be easily removed for inspection and maintenance. Louvered side panels provide ample motor ventilation.

POSITIVE SCREW ADJUSTMENT

Motor platform has threaded rods for ease in adjusting motor and setting proper belt tension.

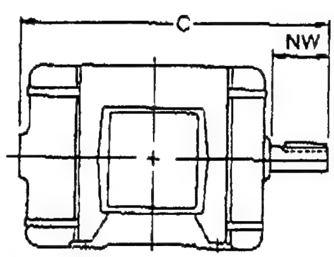
VIBRATION ISOLATION

Rubber-in-shear or spring-type isolation rails.



MAXIMUM MOTOR SIZE LIMITS

Motor frame sizes vary in length with different motor manufacturers. To determine whether a specific motor will fit, the frame size should be equal to or smaller than the maximum shown and the case length [NEMA C minus NEMA NW] must be equal to or less than the maximum allowable dimension shown.



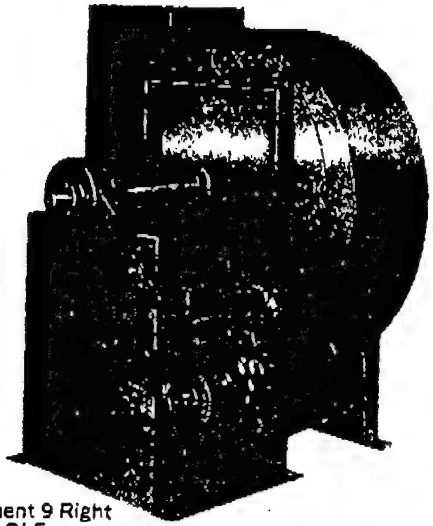
DIMENSIONS [inches]

Size	Maximum motor frame		Maximum motor case length [C-NW]
	Open	TE	
144	184T	184T	14½
174	215T	215T	16⅝
194	215T	215T	16⅝
224	256T	254T	18⅝
264	256T	254T	18⅝
294	284T	254T	19½
334	324T	286T	22½
364	324T	286T	22½

arrangements

NOTE: See page 6 for unitary base option which provides packaged concept with larger fans and motors.

ARRANGEMENT 9



Size 294
Arrangement 9 Right
Series 20 GI Fan

Packaged arrangement with motor slide base mounted on fan pedestal. Motor can be mounted on the left or right side of fan pedestal. Refer to chart below for maximum motor size limits.

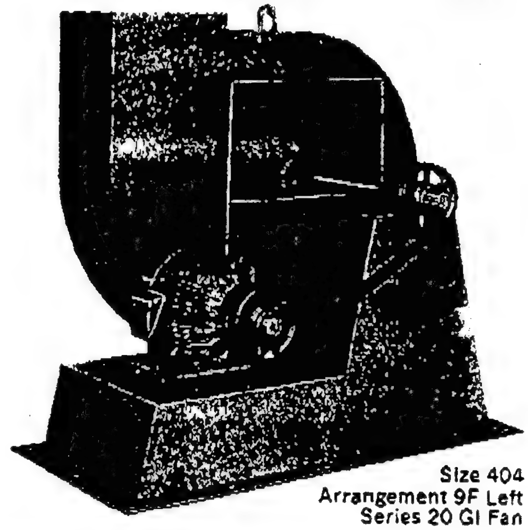
Maximum temperatures—standard fan: 300°F., heat fan: 600°F. Refer to page 11 for heat fan construction details.

Note: Motors weighing more than 600 pounds require special construction...consult nyb.

MAXIMUM MOTOR SIZE LIMITS

Size	Maximum motor case length* [C-NW] 300°	Maximum motor case length* [C-NW] 600°	Maximum BL†
144	10¼	8¾	11½
174	13¼	11¾	12⅞
194	16	14½	16⅛
224	17	15½	20⅜
264	20	18½	22¼
294	22½	21	26⅝
334	24	22½	27⅞
364	26½	25	31⅛
404	24	22½	34⅞
454	26	24½	39⅜
504	28½	27	44⅞
574	29¼	27¾	51⅞
644	32	30½	38
714	35	33½	44
784	39	37½	46
854	43	41½	51

ARRANGEMENT 9F



Size 404
Arrangement 9F Left
Series 20 GI Fan

Available in Sizes 404 through 574. Integral motor platform provides packaged convenience for larger motor horsepowers than standard Arrangement 9. Motor platform can be on the left or right side of fan pedestal. Refer to chart below for minimum and maximum motor size limits.

Maximum temperatures—standard fan: 300°F., heat fan: 600°F. Refer to page 11 for heat fan construction details.

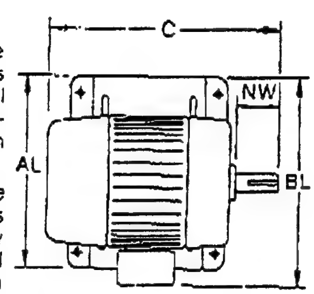
AVAILABLE MOTOR SIZE LIMITS

Size	Maximum motor case length* [C-NW] 300°	Maximum motor case length* [C-NW] 600°	Minimum motor frame size
404	27¼	25¾	286T
454	28½	27	324T
504	30¼	28¾	364T
574	30¼	28¾	364T

FOOTNOTES

*Maximum motor case length [NEMA C minus NEMA NW] must be equal to or less than the maximum allowable dimension shown.

†Maximum motor rail size [NEMA AL dimension plus junction box if box is below motor=BL] must be equal to or less than dimension shown.



194 DH

Inlet diameter: 11" O.D. | **Wheel diameter: 19⅛"**

Outlet area: .660 sq. ft. inside | **Wheel circumference: 5.01 ft.**

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
660	1000	1005	0.44	1401	0.91	1709	1.43	1971	1.99	2204	2.61	2411	3.24	2609	3.94	2789	4.66	2960	5.41	3121	6.19	3279	7.02
792	1200	1017	0.50	1408	1.00	1714	1.57	1972	2.16	2204	2.82	2410	3.49	2603	4.21	2782	4.96	2952	5.75	3114	6.57	3267	7.41
924	1400	1033	0.56	1420	1.11	1721	1.71	1979	2.35	2206	3.03	2414	3.76	2603	4.50	2783	5.30	2950	6.11	3106	6.94	3261	7.83
1056	1600	1053	0.63	1432	1.22	1730	1.86	1985	2.54	2212	3.27	2416	4.02	2606	4.81	2784	5.64	2948	6.48	3105	7.35	3259	8.27
1188	1800	1074	0.70	1446	1.33	1742	2.02	1996	2.75	2221	3.51	2423	4.30	2610	5.13	2785	5.98	2951	6.87	3108	7.79	3256	8.72
1320	2000	1102	0.79	1462	1.46	1755	2.19	2005	2.95	2226	3.75	2429	4.58	2618	5.46	2792	6.36	2956	7.28	3110	8.22	3261	9.21
1452	2200	1131	0.88	1480	1.59	1769	2.36	2018	3.17	2238	4.01	2440	4.89	2624	5.79	2800	6.74	2963	7.70	3118	8.69	3265	9.70
1584	2400	1163	0.98	1503	1.73	1785	2.54	2029	3.38	2250	4.28	2452	5.21	2636	6.15	2805	7.11	2971	8.13	3126	9.17	3270	10.2
1716	2600	1198	1.10	1526	1.88	1803	2.73	2046	3.62	2263	4.55	2461	5.51	2645	6.51	2817	7.53	2978	8.57	3131	9.63	3276	10.7
1980	3000	1272	1.37	1580	2.22	1844	3.14	2081	4.12	2291	5.13	2487	6.17	2670	7.26	2840	8.36	2998	9.48	3151	10.6	3294	11.8
2244	3400	1353	1.70	1644	2.63	1896	3.62	2120	4.66	2330	5.77	2518	6.88	2695	8.03	2862	9.22	3021	10.4	3170	11.7	3316	12.9
2508	3800	1437	2.09	1714	3.10	1955	4.16	2172	5.29	2369	6.44	2554	7.64	2727	8.87	2894	10.2	3048	11.4	3197	12.8	3337	14.1
2772	4200	1526	2.56	1790	3.64	2018	4.77	2225	5.96	2420	7.21	2597	8.47	2767	9.79	2929	11.1	3081	12.5	3225	13.9	3368	15.3
3036	4600	1616	3.09	1869	4.26	2068	5.47	2288	6.74	2473	8.04	2647	9.39	2811	10.8	2968	12.2	3117	13.6	3263	15.1	3398	16.6
3300	5000	1709	3.70	1952	4.97	2162	6.25	2355	7.60	2531	8.96	2700	10.4	2860	11.8	3013	13.3	3158	14.8	3297	16.4		
3564	5400	1804	4.41	2039	5.77	2241	7.14	2424	8.54	2597	9.99	2759	11.5	2915	13.0	3061	14.5	3204	16.2	3341	17.8		
3828	5800	1903	5.23	2126	6.66	2322	8.13	2498	9.58	2666	11.1	2822	12.7	2973	14.3	3117	15.9	3254	17.5	3390	19.3		

224 DH

Inlet diameter: 13" O.D. | **Wheel diameter: 22⅝"**

Outlet area: .930 sq. ft. inside | **Wheel circumference: 5.92 ft.**

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
930	1000	851	0.53	1195	1.09	1467	1.72	1696	2.40	1900	3.13	2086	3.92	2254	4.74	2413	5.62	2561	6.53	2700	7.48	2836	8.49
1116	1200	861	0.62	1195	1.24	1463	1.92	1692	2.65	1895	3.43	2075	4.24	2245	5.11	2402	6.02	2551	6.98	2690	7.95	2822	8.97
1302	1400	876	0.71	1201	1.39	1463	2.13	1689	2.91	1888	3.74	2072	4.62	2240	5.53	2394	6.47	2541	7.45	2683	8.50	2815	9.55
1488	1600	895	0.81	1211	1.55	1467	2.35	1689	3.19	1886	4.08	2067	5.00	2234	5.96	2388	6.96	2536	8.00	2674	9.06	2805	10.1
1674	1800	916	0.91	1224	1.72	1473	2.58	1693	3.49	1885	4.42	2065	5.41	2229	6.42	2384	7.47	2529	8.54	2667	9.66	2796	10.8
1860	2000	940	1.04	1240	1.91	1485	2.83	1698	3.79	1891	4.80	2065	5.82	2229	6.90	2381	8.00	2526	9.14	2661	10.3	2793	11.5
2046	2200	966	1.17	1259	2.10	1498	3.08	1707	4.11	1895	5.17	2068	6.26	2231	7.40	2381	8.56	2524	9.74	2659	10.9	2789	12.2
2232	2400	992	1.31	1278	2.31	1513	3.35	1719	4.44	1904	5.56	2073	6.71	2235	7.92	2381	9.11	2524	10.4	2658	11.6	2786	12.9
2418	2600	1021	1.48	1302	2.54	1530	3.64	1731	4.78	1916	5.98	2083	7.19	2238	8.42	2386	9.70	2525	11.0	2661	12.4	2787	13.7
2790	3000	1082	1.85	1349	3.02	1570	4.25	1765	5.53	1942	6.84	2104	8.17	2257	9.54	2400	10.9	2536	12.3	2668	13.8	2792	15.3
3162	3400	1148	2.30	1404	3.60	1617	4.95	1805	6.34	1979	7.79	2134	9.23	2284	10.7	2424	12.2	2556	13.8	2685	15.4	2804	16.9
3534	3800	1218	2.84	1462	4.26	1669	5.73	1850	7.24	2018	8.81	2170	10.4	2317	12.0	2452	13.6	2581	15.3	2704	17.0	2823	18.7
3906	4200	1292	3.48	1523	5.00	1724	6.60	1902	8.25	2063	9.92	2213	11.6	2353	13.3	2487	15.1	2611	16.9	2735	18.7	2851	20.5
4278	4600	1369	4.23	1588	5.86	1780	7.57	1953	9.33	2110	11.1	2259	13.0	2395	14.8	2523	16.7	2650	18.6	2765	20.5	2879	22.4
4650	5000	1451	5.12	1656	6.84	1840	8.65	2009	10.5	2163	12.5	2307	14.4	2441	16.4	2567	18.4	2689	20.4	2804	22.4		
5022	5400	1533	6.12	1725	7.93	1904	9.86	2066	11.9	2218	13.9	2356	16.0	2488	18.1	2614	20.2	2732	22.3	2847	24.5		
5394	5800	1615	7.25	1801	9.20	1972	11.2	2128	13.3	2273	15.5	2410	17.7	2541	19.9	2663	22.2	2777	24.4	2889	26.7		

264 DH

Inlet diameter: 15" O.D. | **Wheel diameter: 26⅛"**

Outlet area: 1.24 sq. ft. inside | **Wheel circumference: 6.84 ft.**

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1240	1000	737	0.71	1034	1.46	1270	2.30	1469	3.20	1645	4.18	1806	5.24	1952	6.33	2089	7.50	2218	8.72	2338	9.99	2456	11.3
1488	1200	746	0.82	1035	1.65	1267	2.56	1465	3.54	1641	4.58	1797	5.66	1944	6.82	2080	8.04	2210	9.31	2329	10.6	2444	12.0
1736	1400	759	0.95	1040	1.86	1267	2.84	1463	3.89	1635	4.99	1794	6.17	1939	7.38	2073	8.64	2201	9.95	2323	11.3	2438	12.7
1984	1600	775	1.08	1049	2.07	1271	3.14	1463	4.27	1633	5.44	1790	6.68	1934	7.96	2068	9.29	2196	10.7	2316	12.1	2429	13.5
2232	1800	793	1.22	1060	2.30	1276	3.44	1466	4.66	1632	5.90	1788	7.22	1931	8.57	2065	9.97	2190	11.4	2310	12.9	2422	14.4
2480	2000	814	1.39	1074	2.55	1286	3.78	1470	5.06	1637	6.40	1788	7.77	1930	9.21	2062	10.7	2188	12.2	2304	13.7	2419	15.3
2728	2200	836	1.56	1090	2.81	1297	4.12	1478	5.49	1641	6.90	1791	8.36	1932	9.87	2062	11.4	2186	13.0	2303	14.6	2415	16.3
2976	2400	859	1.76	1107	3.08	1310	4.47	1489	5.93	1649	7.42	1796	8.96	1936	10.6	2062	12.2	2186	13.8	2302	15.5	2413	17.2
3224	2600	884	1.97	1127	3.39	1325	4.85	1499	6.38	1659	7.98	1804	9.60	1938	11.2	2066	12.9	2186	14.7	2305	16.5	2413	18.3
3720	3000	937	2.47	1168	4.04	1360	5.68	1529	7.37	1682	9.13	1822	10.9	1955	12.7	2078	14.6	2196	16.5	2311	18.4	2418	20.4
4216	3400	995	3.08	1216	4.81	1401	6.61	1563	8.46	1714	10.4	1848	12.3	1978	14.3	2099	16.3	2213	18.4	2325	20.5	2428	22.6
4712	3800	1055	3.80	1266	5.68	1445	7.65	1602	9.66	1748	11.7	1879	13.8	2006	16.0	2123	18.2	2235	20.4	2342	22.6	2445	24.9
5208	4200	1119	4.65	1319	6.68	1493	8.81	1647	11.0	1787	13.2	1917	15.5	2038	17.8	2154	20.2	2261	22.5	2366	24.9	2469	27.4
5704	4600	1186	5.65	1375	7.82	1541	10.1	1691	12.4	1827	14.8	1956	17.3	2074	19.8	2185	22.2	2295	24.8	2395	27.3	2493	29.9
6200	5000	1257	6.83	1434	9.12	1593	11.5	1740	14.1	1873	16.5	1997	19.2	2114	21.9	2223	24.5	2329	27.2	2428	29.9		
6696	5400	1328	8.16	1494	10.6	1649	13.2	1789	15.8	1920	18.6	2040	21.3	2155	24.1	2263	26.9	2366	29.8	2466	32.7		
7192	5800	1399	9.67	1560	12.3	1708	15.0	1843	17.8	1968	20.6	2087	23.5	2201	26.6	2306	29.5	2405	32.5	2502	35.6		

Performance shown is for Series 20 GI Fans with outlet ducts and with inlet ducts. BHP shown does not include belt drive losses.

404 DH

Inlet diameter: 23" O.D. | Wheel diameter: 40"

Outlet area: 2.90 sq. ft. inside | Wheel circumference: 10.47 ft.

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
2900	1000	467	1.45	658	3.16	810	5.09	939	7.18	1053	9.39	1157	11.8	1252	14.2	1342	16.8	1425	19.4	1506	22.2	1581	25.1
3480	1200	472	1.67	657	3.55	806	5.66	933	7.92	1046	10.3	1149	12.9	1244	15.5	1333	18.3	1417	21.2	1496	24.1	1570	27.1
4060	1400	480	1.92	659	3.96	805	6.24	930	8.70	1042	11.3	1143	14.0	1237	16.9	1325	19.8	1408	22.9	1487	26.0	1561	29.2
4640	1600	489	2.20	664	4.40	806	6.85	929	9.47	1039	12.3	1140	15.2	1233	18.2	1318	21.3	1400	24.5	1480	27.9	1552	31.3
5220	1800	501	2.51	671	4.88	809	7.49	929	10.3	1038	13.2	1137	16.3	1229	19.5	1315	22.9	1396	26.3	1474	29.8	1546	33.4
5800	2000	512	2.85	679	5.39	814	8.16	937	11.1	1038	14.2	1135	17.5	1227	20.9	1312	24.4	1392	28.0	1469	31.7	1541	35.4
6380	2200	526	3.23	689	5.94	820	8.86	936	12.0	1041	15.3	1136	18.7	1275	22.2	1310	25.9	1389	29.7	1464	33.5	1536	37.4
6960	2400	540	3.64	699	6.53	829	9.62	941	12.9	1044	16.3	1140	20.0	1227	23.7	1309	27.4	1388	31.4	1463	35.5	1533	39.5
7540	2600	555	4.10	710	7.15	838	10.4	949	13.9	1049	17.5	1142	21.2	1228	25.0	1312	29.1	1388	33.2	1463	37.4	1532	41.6
8700	3000	585	5.14	736	8.58	859	12.2	967	16.0	1064	19.9	1154	24.0	1238	28.2	1317	32.4	1394	36.9	1464	41.4	1534	46.0
9860	3400	617	6.36	764	10.2	883	14.1	987	18.2	1082	22.5	1170	26.9	1251	31.4	1329	36.1	1401	40.8	1471	45.6	1538	50.5
11020	3800	651	7.80	793	12.0	910	16.4	1010	20.8	1103	25.4	1188	30.1	1268	35.0	1343	39.9	1414	44.9	1483	50.1	1549	55.4
12180	4200	687	9.51	823	14.1	937	18.8	1036	23.6	1127	28.6	1209	33.6	1287	38.8	1361	44.1	1431	49.5	1496	54.8	1561	60.4
13340	4600	724	11.5	855	16.5	966	21.6	1063	26.7	1152	32.1	1233	37.5	1308	42.9	1380	48.5	1448	54.1	1515	60.0	1577	65.8
14500	5000	762	13.8	888	19.1	996	24.6	1092	30.2	1179	35.9	1259	41.7	1333	47.5	1404	53.5	1470	59.4	1533	65.4	1597	71.8
15660	5400	802	16.4	923	22.1	1028	28.0	1121	33.9	1206	40.0	1284	46.0	1357	52.2	1427	58.6	1494	65.0	1555	71.3	1616	77.9
16820	5800	842	19.3	958	25.4	1060	31.7	1152	38.1	1235	44.4	1311	50.9	1384	57.5	1452	64.1	1516	70.8	1579	77.6		

454 DH

Inlet diameter: 26" O.D. | Wheel diameter: 45¼"

Outlet area: 3.69 sq. ft. inside | Wheel circumference: 11.81 ft.

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
3690	1000	414	1.83	583	4.00	718	6.45	832	9.10	934	11.9	1025	14.9	1111	18.1	1190	21.3	1263	24.7	1335	28.2	1402	31.8
4428	1200	418	2.12	583	4.51	714	7.17	828	10.1	928	13.2	1018	16.4	1102	19.7	1181	23.3	1255	26.9	1325	30.7	1392	34.5
5166	1400	425	2.44	584	5.02	713	7.92	824	11.0	924	14.4	1013	17.8	1096	21.4	1174	25.2	1248	29.1	1317	33.0	1383	37.1
5904	1600	434	2.79	588	5.58	714	8.69	823	12.0	921	15.6	1010	19.3	1093	23.2	1170	27.2	1243	31.3	1312	35.5	1376	39.7
6642	1800	444	3.18	595	6.20	717	9.50	824	13.1	920	16.8	1008	20.7	1089	24.8	1165	29.0	1237	33.4	1300	37.9	1371	42.4
7380	2000	454	3.61	601	6.83	721	10.4	826	14.1	920	18.1	1007	22.2	1087	26.5	1163	31.0	1734	35.6	1302	40.3	1366	45.0
8118	2200	466	4.10	610	7.54	727	11.2	830	15.2	922	19.4	1007	23.7	1087	28.3	1161	32.9	1231	37.7	1298	42.6	1362	47.6
8856	2400	478	4.61	620	8.29	734	12.2	834	16.4	925	20.7	1010	25.4	1088	30.1	1162	35.0	1230	39.9	1297	45.1	1361	50.4
9594	2600	492	5.20	629	9.08	742	13.2	841	17.6	930	22.2	1013	26.9	1090	31.9	1162	37.0	1230	42.2	1297	47.6	1358	52.9
11070	3000	519	6.52	653	10.9	761	15.5	857	20.3	943	25.2	1023	30.4	1098	35.8	1168	41.2	1235	46.9	1298	52.6	1360	58.5
12546	3400	547	8.07	677	12.9	782	18.0	875	23.2	959	28.6	1037	34.2	1109	39.9	1178	45.9	1242	51.8	1304	57.9	1364	64.2
14022	3800	577	9.91	703	15.3	806	20.8	895	26.4	978	32.3	1053	38.3	1124	44.4	1190	50.7	1253	57.1	1315	63.8	1373	70.5
15498	4200	609	12.1	730	17.9	831	23.9	919	30.1	999	36.4	1071	42.7	1141	49.3	1206	56.0	1268	62.9	1326	69.7	1384	76.8
16974	4600	642	14.6	758	20.9	856	27.4	942	34.0	1021	40.8	1093	47.6	1159	54.5	1223	61.6	1283	68.8	1343	76.3	1396	83.7
18450	5000	676	17.5	787	24.3	883	31.2	968	38.4	1045	45.6	1116	53.0	1181	60.4	1244	68.0	1303	75.5	1359	83.2	1415	91.3
19926	5400	711	20.8	818	28.1	911	35.6	994	43.1	1069	50.9	1138	58.5	1202	66.4	1265	74.5	1324	82.7	1378	90.7	1433	99.1
21402	5800	746	24.5	849	32.3	939	40.3	1021	48.4	1094	56.5	1163	64.8	1226	73.1	1287	81.6	1344	90.0	1399	98.7	1452	107

504 DH

Inlet diameter: 29" O.D. | Wheel diameter: 50½"

Outlet area: 4.62 sq. ft. inside | Wheel circumference: 13.22 ft.

CFM	OV	2"SP		4"SP		6"SP		8"SP		10"SP		12"SP		14"SP		16"SP		18"SP		20"SP		22"SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4620	1000	369	2.27	521	4.97	641	8.03	743	11.3	834	14.9	916	18.6	992	22.5	1063	26.6	1129	30.8	1192	35.2	1252	39.7
5544	1200	373	2.63	521	5.60	638	8.93	739	12.6	829	16.4	911	20.5	985	24.6	1055	29.0	1122	33.6	1184	38.3	1243	43.1
6468	1400	380	3.02	522	6.25	637	9.86	736	13.8	825	17.9	905	22.2	981	26.8	1049	31.4	1115	36.3	1178	41.3	1236	46.4
7392	1600	387	3.47	526	6.97	638	10.8	735	15.0	822	19.4	902	24.1	976	28.9	1045	33.9	1110	39.1	1172	44.3	1229	49.6
8316	1800	396	3.96	531	7.71	640	11.8	736	16.3	822	21.0	900	25.9	973	31.0	1041	36.3	1105	41.7	1167	47.3	1224	53.0
9240	2000	406	4.51	537	8.51	644	12.9	738	17.6	822	22.5	900	27.8	971	33.1	1039	38.7	1102	44.4	1163	50.3	1220	56.3
10164	2200	416	5.10	545	9.39	649	14.0	741	19.0	824	24.2	901	29.7	971	35.3	1037	41.1	1100	47.1	1161	53.3	1218	59.6
11088	2400	427	5.74	553	10.3	656	15.2	746	20.5	827	25.9	902	31.7	972	37.5	1038	43.7	1100	49.9	1159	56.3	1216	62.9
12012	2600	439	6.48	562	11.3	663	16.5	751	22.0	831	27.7	905	33.6	974	39.9	1038	46.2	1099	52.7	1158	59.4	1215	66.3
13860	3000	463	8.12	583	13.6	680	19.3	765	25.3	842	31.5	914	38.0	981	44.7	1043	51.5	1103	58.6	1159	65.7	1215	73.1
15708	3400	489	10.1	604	16.1	699	22.4	781	28.9	857	35.7	926	42.8	991	49.9	1052	57.3	1110	64.7	1166	72.6	1218	80.3
17556	3800	516	12.4	628	19.1	720	26.0	801	33.1	873	40.4	941	47.8	1004	55.5	1064	63.4	1120	71.4	1175	79.7	1227	88.1
19404	4200	544	15.1	652	22.4	742	29.9	821	37.6	892	45.5	959	53.6	1019	61.7	1077	70.0	1133	78.6	1186	87.4	1236	96.0
21252	4600	573	18.2	677	26.1	765	34.2	841	42.5	912	50.9	976	59.5	1036	68.2	1092	77.0	1147	86.1	1199	95.5	1249	105
23100	5000	604	21.8	703	30.3	789	39.1	864	48.0	933	57.0	997	66.2	1055	75.4	1112	85.0	1164	94.4	1214	104	1264	114
24948	5400	635	26.0	731	35.1	814	44.4	888	53.9	955	63.8	1018	73.4	1076	83.3	1130	93.2	1183	103	1231	113	1280	124
26796	5800	666	30.6	759	40.4	839	50.3	912	60.5	977	70.6	1039	81.1	1096	91.4	1150	102	1201	113	1250	123	1297	134

Performance shown is for Series 20 GI Fans with outlet ducts and with inlet ducts. BHP shown does not include belt drive losses.

DIMENSIONS

L, M, and D are outside dimensions.

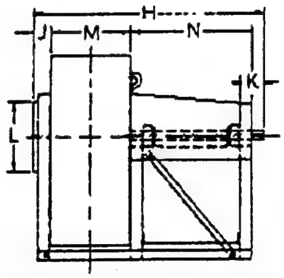
J is from housing side over inlet collar.

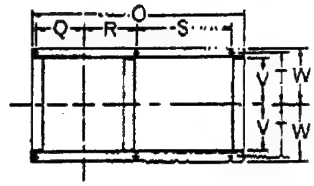
Tolerance: ±1/8"

Dimensions not to be used for construction unless certified.

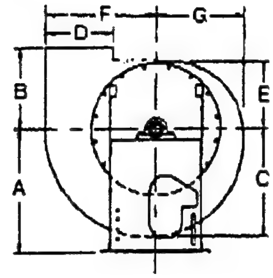
Refer to page 4 for maximum motor size limits.

ARRANGEMENT 10





Inlet bracket is omitted on Sizes 144 and 174.

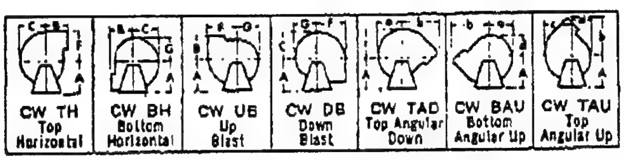


DIMENSIONS [Inches]

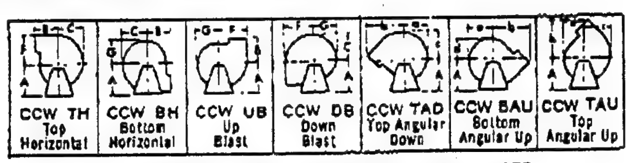
Size	A	B	C	D	E	F	G	H	J	K	L	M	N	O
144	15 1/4	10 1/2	11 1/8	8 1/4	9 3/8	12	10 1/4	30	1 1/8	2 1/2	9	7 7/8	20	19 7/8
174	17 1/2	12 5/8	13 3/8	10 1/8	11 1/8	14 1/2	12 1/4	34 1/8	1 5/8	3	11	9 1/2	22	21 7/8
194	21 1/4	14	16	10 1/4	11 7/8	18	13 7/8	36 3/8	3 1/8	3 1/2	11	9 3/4	22	33 7/8
224	25 1/2	16 1/2	18 7/8	13	14	21 1/4	16 3/8	41 3/8	3 1/8	4	13	10 3/4	26	38 7/8
264	28	18 1/2	21 1/4	15	16 1/8	24 1/2	18 7/8	44 1/2	4 1/8	4 1/2	15	12 3/8	26	41 1/2
294	32 1/2	21	24 5/8	16 7/8	18 1/4	27 3/4	21 3/8	48	4 1/8	5 1/2	17	14	26 7/8	44
334	39 1/2	23	27 3/8	18 3/4	20 3/8	30 7/8	23 7/8	53 1/8	4 1/8	6	19	15 5/8	29 7/8	48 1/8
364	39 1/2	25 1/2	30 1/4	20 1/4	22 1/2	34 1/8	26 3/8	56	5 1/4	6	21	17 1/4	30	50 3/8

Size	Q	R	S	T	V	W	a	b	c	d	Shaft diameter	Keyway	Base holes
144	—	5 7/8	16 3/4	7 3/8	6 1/2	8	10 3/4	16	11 1/2	9 3/4	1 7/16	3/8 x 3/16	9/16
174	—	6 5/8	18 3/8	8 7/8	8	9 1/2	13 1/8	19 1/4	13 3/4	11 1/2	1 7/16	3/8 x 3/16	9/16
194	6	7 1/4	17 3/8	9 3/8	8 1/4	10 1/4	15	22 5/8	17	13	1 11/16	3/8 x 3/16	9/16
224	6 1/2	8 1/4	20 3/8	10 7/8	9 3/4	11 3/4	17 5/8	26 5/8	20	15 1/4	1 15/16	1/2 x 1/4	9/16
264	7 7/8	9 1/8	19 7/8	12 1/4	11	13	20 1/4	30 3/8	23	17 1/2	1 15/16	1/2 x 1/4	3/4
294	8 5/8	10 1/8	20 3/4	13 5/8	11 1/4	14 3/4	23	34 3/8	26 1/8	19 7/8	1 15/16	1/2 x 1/4	3/4
334	9 3/8	11	23 3/4	16	14	17	25 3/4	38 1/8	29 1/4	22 3/8	2 3/16	1/2 x 1/4	3/4
364	10 1/4	11 7/8	23 3/4	16	14	17	28 1/2	42 1/8	32 1/4	24 5/8	2 3/16	1/2 x 1/4	3/4

FAN DISCHARGES – VIEWED FROM DRIVE SIDE

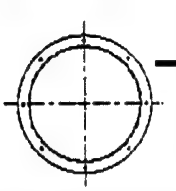


Clockwise -- Angular discharges at 45°



Counterclockwise — Angular discharges at 45°

FLANGED INLET OPTION



Furnished with holes starting on vertical centerline.

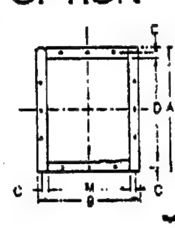
Inlet bar sizes:
Sizes 144-174
10 ga. x 1 1/4
Size 194
7 ga. x 1 1/4
Sizes 224-364
1/4 x 1 1/4
Sizes 404-854
1/4 x 2

DIMENSIONS [Inches]

Size	I.D.*	B.C.	O.D.	Holes No.	Holes Dia.
144	8 3/4	10 1/4	11 1/2	6	7/16
174	10 3/4	12 1/4	13 1/2	6	7/16
194	10 5/8	12 1/2	14	8	7/16
224	12 5/8	14 1/2	16	8	7/16
264	14 5/8	16 1/2	18	8	7/16
294	16 5/8	18 1/2	20	8	7/16
334	18 5/8	20 1/2	22	16	7/16
364	20 5/8	22 1/2	24	16	7/16
404	22 5/8	25	27	16	9/16
454	25 5/8	28	30	16	9/16
504	28 5/8	31	33	16	9/16
574	32 5/8	35	37	16	9/16
644	36 1/2	39	41	24	9/16
714	40 1/2	43	45	24	9/16
784	44 1/2	47	49	24	9/16
854	48 1/2	51	53	24	9/16

*Dimension shown is I.D. of inlet collar

FLANGED OUTLET OPTION



1. Mounted flush with edge of housing outlet.

2. Holes furnished on 4" centers on centerline.

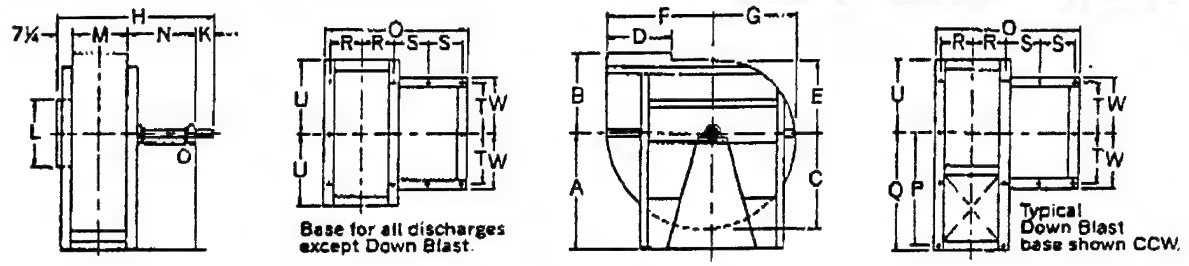
Outlet flange angles
Sizes 144-174
1 1/4 x 1 1/4 x 3/16
Sizes 194-364
1 1/2 x 1 1/2 x 3/16
Sizes 404-854
2 x 2 x 3/16

DIMENSIONS [Inches]

Size	A	B	C	D*	M*	Holes No.	Holes Dia.
144	10 3/4	10 3/8	3/4	8 1/4	7 7/8	8	7/16
174	12 5/8	12	3/4	10 1/8	9 1/2	12	7/16
194	13 1/4	12 3/4	7/8	10 1/4	9 3/4	12	7/16
224	16	13 3/4	7/8	13	10 3/4	12	7/16
264	18	15 3/8	7/8	15	12 3/8	16	7/16
294	19 7/8	17	7/8	16 7/8	14	16	7/16
334	21 7/8	18 5/8	7/8	18 3/4	15 5/8	16	7/16
364	23 1/4	20 1/4	7/8	20 1/4	17 1/4	20	7/16
404	26 7/8	23	1 1/8	22 7/8	19	24	9/16
454	29 3/4	25 3/8	1 1/8	25 3/4	21 3/8	24	9/16
504	32 3/4	27 7/8	1 1/8	28 3/4	23 7/8	24	9/16
574	36 5/8	31 1/8	1 1/8	32 5/8	27 1/8	32	9/16
644	40 5/8	34 1/2	1 1/8	36 5/8	30 1/2	32	9/16
714	44 5/8	37 5/8	1 1/8	40 3/8	33 5/8	36	9/16
784	48 3/8	40 7/8	1 1/8	44 3/8	36 7/8	40	9/16
854	52 1/4	44 1/8	1 1/8	48 1/4	40 1/8	44	9/16

*Dimension shown is inside flange, outside outlet. Deduct housing material thickness to determine inside dimension of discharge

ARRANGEMENTS 1 and 9 — SIZES 644-854

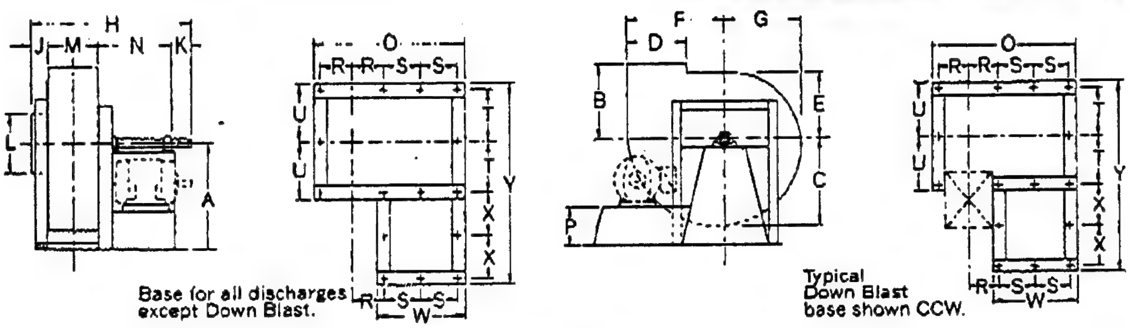


DIMENSIONS [Inches]

Size	Wheel dia.	A TH	A BH	A UB	A DB	A TAD	A BAU	A TAU	B	C	D	E	F	G	H	K	L	M	N
644	64 3/8	49	64 1/2	55 1/2	43	45	59	52	43	53 3/8	36 1/2	39 3/4	60 1/8	46 1/2	84 1/4	9 1/2	37	30 1/2	37
714	71 1/4	54	71	61 1/2	47 1/2	50	65	57 1/2	47 1/2	59	40 3/8	44	66 3/8	51 1/2	90 7/8	10	41	33 5/8	40
784	78 1/4	59	77	67	52	54 3/4	71	63	52	64 3/4	44 1/4	48 7/8	73	56 1/2	98 5/8	10 1/2	45	36 7/8	44
854	85 1/4	64	83	73	57	60	78 1/2	69	57	70 1/2	48 1/4	52 5/8	79 1/2	61 1/2	106 3/8	11	49	40 1/8	48

Size	O	P	Q	R	S	T	U	W	a	b	c	d	Shaft dia. LS	Shaft dia. DH	Keyway LS	Keyway DH	Base holes
644	77 1/8	62 3/8	65 1/8	17 3/4	18 1/2	30	39 1/8	32 1/4	50 1/4	72 7/8	57	43 1/2	3 7/16	3 7/16	7/8 x 7/16	7/8 x 7/16	1
714	83 1/4	68 7/8	71 3/8	19 3/8	20	33 1/2	43 1/2	35 3/4	55 1/2	80 5/8	62 7/8	48	3 15/16	3 15/16	1 x 1/2	1 x 1/2	1
784	90 1/2	75 1/2	78	21	22	36 1/2	47	38 3/4	60 7/8	88 1/2	69	52 3/4	3 15/16	3 15/16	1 x 1/2	1 x 1/2	1
854	97 3/4	82	84 1/2	22 3/8	24	39 1/2	50 1/2	41 3/4	66 3/8	96 5/8	75	57 3/8	4 7/16	4 7/16	1 x 1/2	1 x 1/2	1

ARRANGEMENT 9F — SIZES 404-574

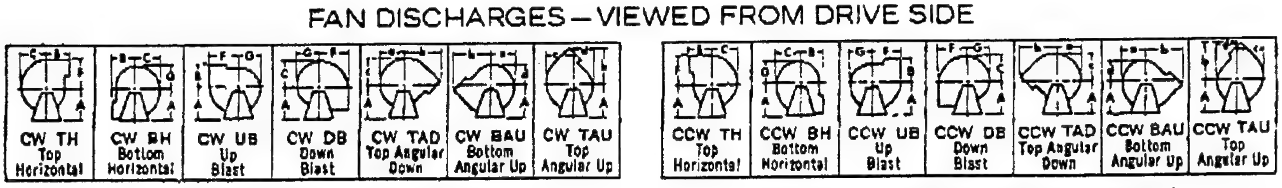


DIMENSIONS [Inches]

Size	Wheel dia.	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P
404	40	40	28	33 1/4	22 7/8	24 3/4	37 3/8	29	65	5 1/4	7 1/2	23	19	33 1/4	60 1/2	13 1/2
454	45 1/8	45	31 1/2	37 1/2	25 3/4	27 7/8	42 1/4	32 3/8	68 7/8	5 1/4	8	26	21 1/8	34 1/4	63 7/8	15
504	50 1/2	50 1/2	34 1/2	41 7/8	28 3/4	31 1/4	47 1/4	36 1/2	74 5/8	6	8 1/2	29	23 7/8	36 1/4	68 3/4	17
574	57 1/2	57 1/2	39	47 1/2	32 5/8	35 1/2	53 5/8	41 1/2	80 3/8	7	9	33	27 1/8	37 1/4	74 5/8	19

Size	R	S	T	U	W	X	Y	a	b	c	d	Shaft dia. LS	Shaft dia. DH	Keyway LS	Keyway DH	Base holes
404	11 3/8	16 5/8	18 3/8	20 3/8	37 1/4	17	75 1/8	31 1/8	46 1/4	35 3/8	27	2 7/16	2 7/16	5/8 x 5/16	5/8 x 5/16	7/8
454	12 7/8	17 1/8	20 1/4	22 1/2	38 1/4	17	78 7/8	35 3/8	52 1/4	40	30 5/8	2 11/16	2 11/16	5/8 x 5/16	5/8 x 5/16	7/8
504	14 1/8	18 1/8	22 1/4	23 3/4	40 1/4	18 1/2	84 1/2	39 3/8	57 3/4	44 5/8	34 1/2	2 15/16	2 15/16	3/4 x 3/8	3/4 x 3/8	1
574	16 1/4	18 5/8	25	27 3/8	42 1/4	18 1/2	91 3/4	44 3/4	65 5/8	50 3/4	38 3/4	2 15/16	2 15/16	3/4 x 3/8	3/4 x 3/8	1

FAN DISCHARGES — VIEWED FROM DRIVE SIDE



Clockwise—Angular discharges at 45°

Counterclockwise—Angular discharges at 45°

GOULDS PUMPS, INC.
7100 S.W. SANDBURG STREET
TIGARD, OREGON 97223
PHONE: (503) 684-2520

RECEIVED
MAY 2 2 1992
WCC/DENVER, COLO

RETURN FAX #
(503) 620-8626

TOTAL QUALITY
Our Job

FAX TRANSMITTAL

DATE SENT: May 18, 1992 TIME SENT: 3:13pm

7 PAGES PLUS COVER SHEET

TO: Woodward & Clyde

ATTN: Joseph Scott

FROM: Michael J. Gay

C.C.

MESSAGE: **Reference:** **Rocky Mountain Arsenal - Budget Proposal**

Thank you for contacting Goulds Pumps concerning your pumping requirements. We are pleased to submit the following budget proposal.

For your H_2SO_4 Injection pump applications, we are offering our Model 3196STX Horizontal ANSI pump with our new 'X-series' bearing frame. The Model 3196 pricing includes 316SS construction with 316SS shaft sleeve, flood oil lubrication, cast iron baseplate, Rexnord coupling, John Crane double mechanical seal with provisions for customer supplied flush, 150# FF flanges, and TEFC Mill & Chem duty motor.

Our best estimate for shipment of the Model 3196STX is 10-12 weeks after receipt of approved drawings and subsequent release to manufacturing.

All pricing for the Model 3196STX is quoted F.O.B. Seneca Falls, NY. Estimated freight is approximately $147.00 for both units.

Any purchase order resulting from this proposal will be subject to Goulds' Standard terms and conditions. Terms of payment will be 100% net thirty (30) days after shipment.

Thank you for considering Goulds Pumps. If you should have any questions concerning this proposal or if we can be of further assistance, please contact our office at your convenience.

Sincerely,

Ron Evancho
Sales Engineer

Michael J. Gay
District Engineer

GOULDS PUMPS, INC.
SENECA FALLS, NEW YORK 13148

CENTRIFUGAL PUMP QUOTATION

REPLY TO:
GOULDS PUMPS, INC.
7100 SW SANDBURG
TIGARD, OR 97223
PHONE: (503)-684-2520

All quotations subject to terms and conditions on the reverse side except as noted on Page ______ attached.

SHIPMENT: Our best estimate at this time is ______ weeks after complete engineering and manufacturing information and full approval to proceed with work.

To: Woodward & Clyde
4582 S. Ulster St. Parkway
Suite 1000
Denver, CO 80257

Date: 5/18/92 Page: 1 of 2
Proposal No.: Budgetary
Revision No.:
Copies:

Attention: Joseph Scott
Inquiry Date: 5/14/92
Inquiry No.:

In answer to your inquiry, we propose to furnish GOULDS PUMPS as described below:

ITEM NO.
EQUIP. NO.
SERVICE H_2SO_4 Injection

Quantity	Model	Size	Rotation
1	3196STX	1X1½-6	RH
Casing	**Impeller**	**Shaft**	**Sleeve**
316SS	316SS	316SS	316SS
Wear Plate	**Lubrication**	**Base Plate**	**Coupling**
-	Oil	Cast Iron	Rexnord ES-2
Mechanical Seal — ~~XXXXX~~			**Imp. Type**
John Crane Type 9T Q/XF51lC1 (Double) Customer Supplied Flush			Open

OPERATING CONDITIONS AND PERFORMANCE

Liquid		Temp. °F	Sp. Gr. @ P.T.
Water/H_2SO_4		-	Assumed 1.0
G.P.M.	**T.D.H.**	**V.P.**	**Visc.**
20	60'	-	-
Eff.	**Rated B.H.P.**	**Max. B.H.P.**	**Suct. Press**
32%	0.95	2.6	-
Disch. Press	**Perf. Curve**	**$NPSH_R$**	**$NPSH_A$**
-	3029-1	15'	Assumed Adequate

Impeller Diameter Rated	Min.	Max.	Bulletin
7.00"	5.50"	8.00"	725.1C4

DRIVER—

H.P.	R.P.M.	Enclosure	Frame	S.F./Insulation
3	1750	TEFC M&C	182T	1.15/F
Phase	**Hertz**	**Voltage**	**Furnished By**	
3	60	460	Goulds	

ITEM	*PRICE	WEIGHT
Pump		
Driver		
Total Unit Price & Weight	$3,770.00ea.	285 lb

WITH THE FOLLOWING ADDITIONS, MODIFICATIONS AND/OR REQUIREMENTS

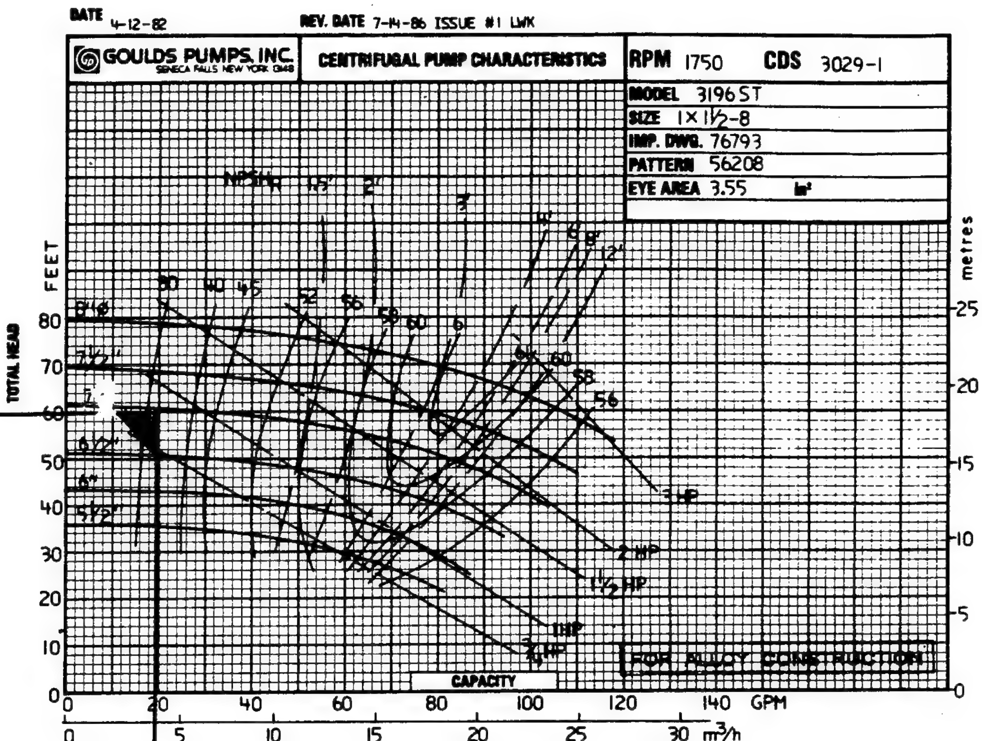
THIS QUOTATION VALID FOR 30 DAYS FROM DATE OF PROPOSAL SHOWN ABOVE.
* PRICES SHOWN ARE F.O.B. SHIPPING POINT
TERMS: NET 30 DAYS - SUBJECT TO CREDIT DEPT. APPROVAL

Michael Gay/Ron Evancho
GOULDS PUMPS, INC.

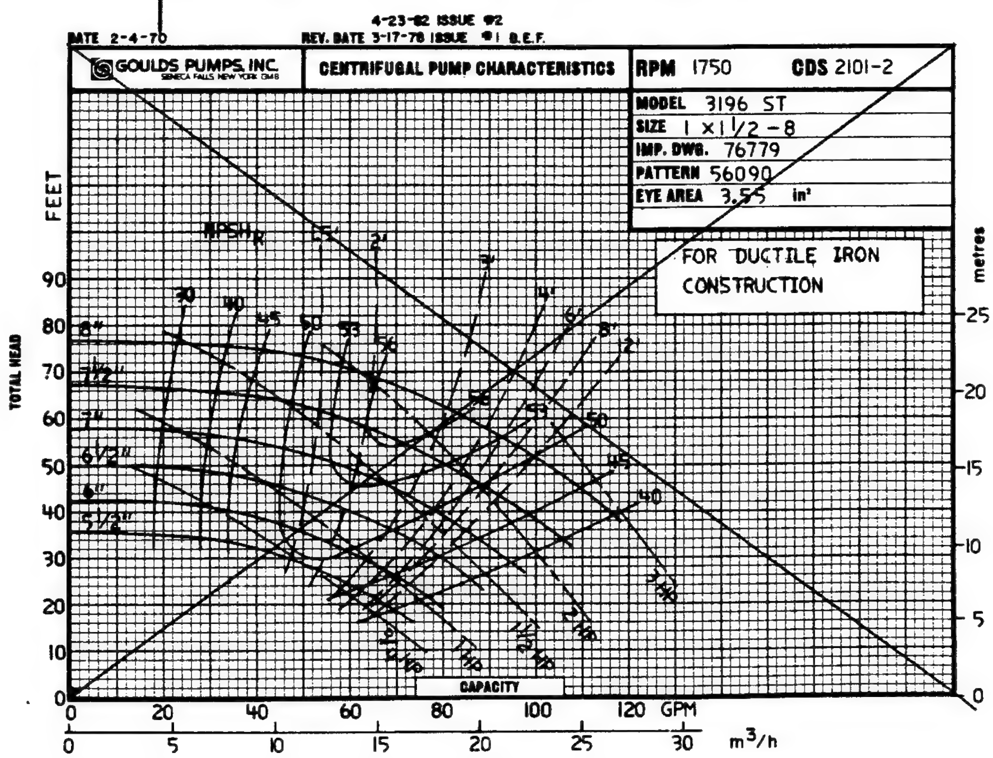
A-848-EF SUP. 9614

Customer WOODWARD & CLYDE Inquiry No. VERBAL Date 5/14/92
Service H_2SO_4 Item No. ______ P.O. No. ______ Date ______
F.O. No. ______ ; 20 GPM; 60' TDH; 1750 RPM; 32 % Eff.; CDS No. 3029-1

1750 RPM



1750 RPM



GOULDS PUMPS, INC.
SENECA FALLS NEW YORK 13148

CENTRIFUGAL PUMP QUOTATION

REPLY TO:
GOULDS PUMPS, INC.
7100 SW SANDBURG
TIGARD, OR 97223
PHONE: (503)-684-2520

All quotations subject to terms and conditions on the reverse side except as noted on Page ________ attached.

SHIPMENT: Our best estimate at this time is ________ weeks after complete engineering and manufacturing information and full approval to proceed with work.

To: Woodward & Clyde
4582 S. Ulster St. Parkway
Suite 1000
Denver, CO 80257

Date: 5/18/92 Page: 2 of 2
Proposal No.: Budgetary
Revision No.:
Copies:

Attention: Joseph Scott
Inquiry Date: 5/14/92
Inquiry No.:

In answer to your inquiry, we propose to furnish GOULDS PUMPS as described below:

ITEM NO.
EQUIP. NO.
SERVICE H_2SO_4 Injection

Quantity	Model	Size	Rotation
1	3196STX	2X3-6	RH
Casing	**Impeller**	**Shaft**	**Sleeve**
316SS	316SS	316SS	316SS
Wear Plate	**Lubrication**	**Base Plate**	**Coupling**
-	Oil	Cast Iron	Rexnord ES-2

Mechanical Seal – ~~XXXXXX~~
John Crane Type 9T
XF1C1 (Double)
Customer Supplied Flush

Imp. Type: Open

OPERATING CONDITIONS AND PERFORMANCE

Liquid		Temp. °F	Sp. Gr. @ P.T.
Water/H_2SO_4		-	Assumed 1.0
G.P.M.	**T.D.H.**	**V.P.**	**Visc.**
170	60'	-	-
Eff.	**Rated B.H.P.**	**Max. B.H.P.**	**Suct. Press**
63.5%	4.1	5.0	-
Disch. Press	**Perf. Curve**	**$NPSH_R$**	**$NPSH_A$**
-	3036-1	9.5'	Assumed Adequate

Impeller Diameter Rated	Min.	Max.	Bulletin
4.38"	4.00"	6.06"	725.1C10

DRIVER–

H.P.	R.P.M.	Enclosure	Frame	S.F./Insulation
5	3500	TEFC M&C	184T	1.15/F
Phase	**Hertz**	**Voltage**	**Furnished By**	
3	60	460	Goulds	

ITEM	*PRICE	WEIGHT
Pump		
Driver		
Total Unit Price & Weight	$3,812.00ea.	303 lb

WITH THE FOLLOWING ADDITIONS, MODIFICATIONS AND/OR REQUIREMENTS

THIS QUOTATION VALID FOR 30 DAYS FROM DATE OF PROPOSAL SHOWN ABOVE.
* PRICES SHOWN ARE F.O.B. SHIPPING POINT

TERMS: NET 30 DAYS - SUBJECT TO CREDIT DEPT. APPROVAL

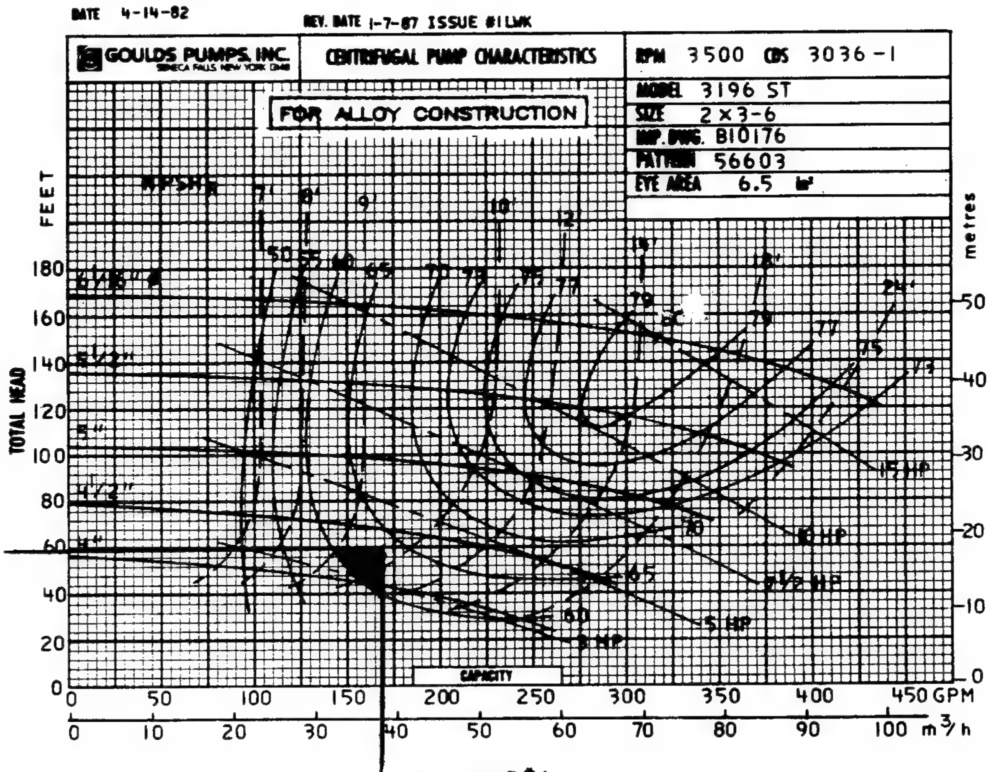
Michael Gay/Ron Evancho
GOULDS PUMPS, INC.

A-848-EF SUP. 9614

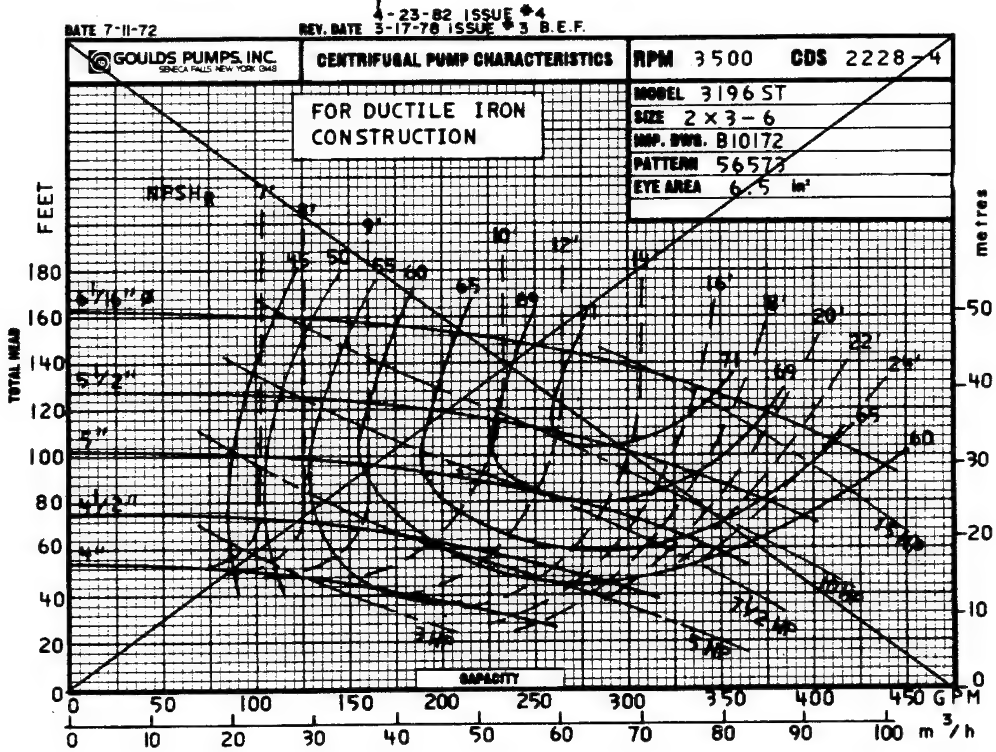
Goulds Model 3196 ST

60 Hz Performance Curve

Customer WOODWARD & CLYDE Inquiry No. VERBAL Date 5/14/92
Service H_2SO_4 INJ. Item No. ______ P.O. No. ______ Date ______
F.O. No. ______; 170 GPM; 60' TDH; 3500 RPM; 63.5 % Eff.; CDS No. 3036-1

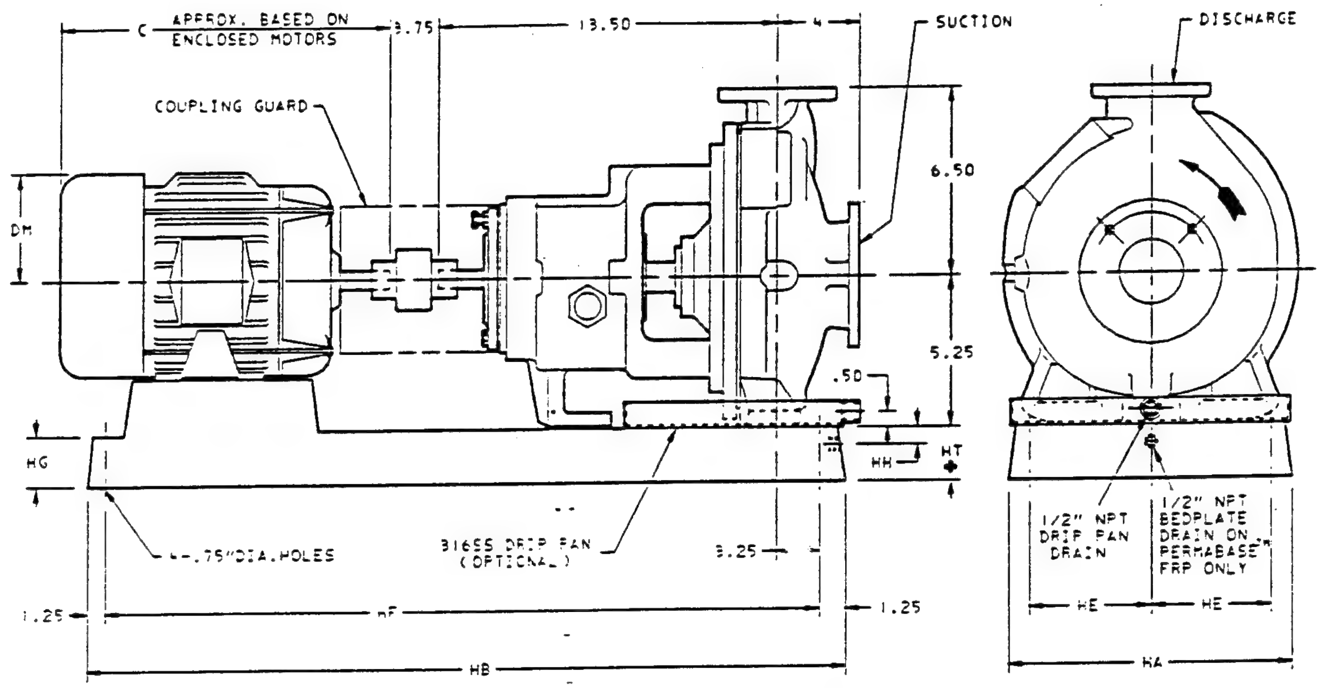


3500 RPM



3500 RPM

GOULDS PUMPS, INC. | INDUSTRIAL PRODUCTS GROUP ENGINEERED PRODUCTS DIV. | PUMP OUTLINE DRAWIN[G] MODEL 3196 STX



MOTOR DIMENSIONS (TEFC)					
	MOTOR FRAME SIZE	C	DM	WT. INCL. CPLG.	BEDPLATE NUMBER
	56	10.50	3.50	35	1
	143T	12.50	3.50	50	1
	145T	13.50	3.50	55	1
	182T	14.50	5.00	85	2
X	184T	15.50	5.00	100	2
	213T	18.00	6.00	150	2
	215T	19.50	6.00	170	2
	254T	22.50	6.50	245	3
	256T	24.00	6.50	285	3
	284T	25.50	7.50	390	3
	284TS	24.50	7.50	360	3
	286T	27.00	7.50	435	3
	286TS	26.00	7.50	425	3

PUMP SIZE				
	DISCHARGE SIZE	SUCTION SIZE	CASING CLASS	WEIGHT
	1	1 1/2	6	84
	1 1/2	3	6	92
X	2	3	6	95
	■ 1	1 1/2	8	100
	■ 1 1/2	3	8	108

AVAILABLE OPTIONS	
BEDPLATE	[X] CAST IRON [ ] FABRICATED STEEL [ ] PERMABASE™ FRP W/ 1/2"NP[T] BEDPLATE DRAIN [ ] FLEX MOUNTED STEEL 1 & 2 SEE DRAWING NO. A04193A [ ] Y-BASE™
316SS DRIP PAN	[ ] FURNISHED [X] NOT FURNISHED
FLANGES	[X] 150# ANSI FLAT FACE [ ] 150# ANSI RAISED FACE [ ] 300# ANSI FLAT FACE ■ [ ] 300# ANSI RAISED FACE ■
COUPLING GUARD FURNISHED BY	[X] GOULDS [ ] OTHERS

BEDPLATE DIMENSIONS															
	NO.	HA	HB	HT			HG			HE	HF	HH	WEIGHT		
				CAST IRON	STEEL	FRP	CAST IRON	STEEL	FRP				CAST IRON	STEEL	FRP
	1	10	35	3.00	2.88	3.19	2.69	2.88	3.00	4.00	32.50	1.19	75	87	22
X	2	12	39	3.25	3.31	3.69	3.06	3.19	3.12	4.50	36.50	1.38	80	102	29
	3	15	46	5.88	5.25	5.94	4.12	3.38	4.00	6.00	43.50	1.44	120	157	52

✚ TOLERANCE IS +.38 -0 FOR CAST IRON BEDPLATE.

■ WHEN 300# FLANGES ARE FURNISHED, DISCHARGE FLANGE WILL BE THREADED, AS FOLLOWS:
1 X 1 1/2 - 8 : 4-5/8-11 UNC-2B
1 1/2 X 3 - 8 : 4-3/4-10 UNC-2B

⊖ WHEN FLEX MOUNTED STEEL BEDPLATE IS REQUIRED FOR MOTOR FRAMES 254T-286TS, SEE DRAWING NO. A03838A

INSTALL FOUNDATION BOLTS IN PIPE SLEEVES. ALLOW FROM .75" TO 1.50" FOR GROUTING. SEE INSTRUCTION BOOK FOR DETAILS.

FOR TAPPED OPENINGS REFER TO DRAWING NO. A04190A

CERTIFIED FOR CONSTRUCTION PURPOSES ONLY WHEN SIGNED.

SIGNATURE ________________ DATE ________

CUSTOMER WOODWARD & CLYDE

GOULDS SERIAL NO.

CUSTOMER P.O. NO.

ITEM NO.

SERVICE H_2SO_4 INJECTION

ISSUE

DRAWING IS NOT TO SCALE
DIMENSIONS IN INCHES
WEIGHTS (LBS) ARE APPROXIMATE

DRAWN DJN 4-9-91
APPROVED RAS 6-24-91

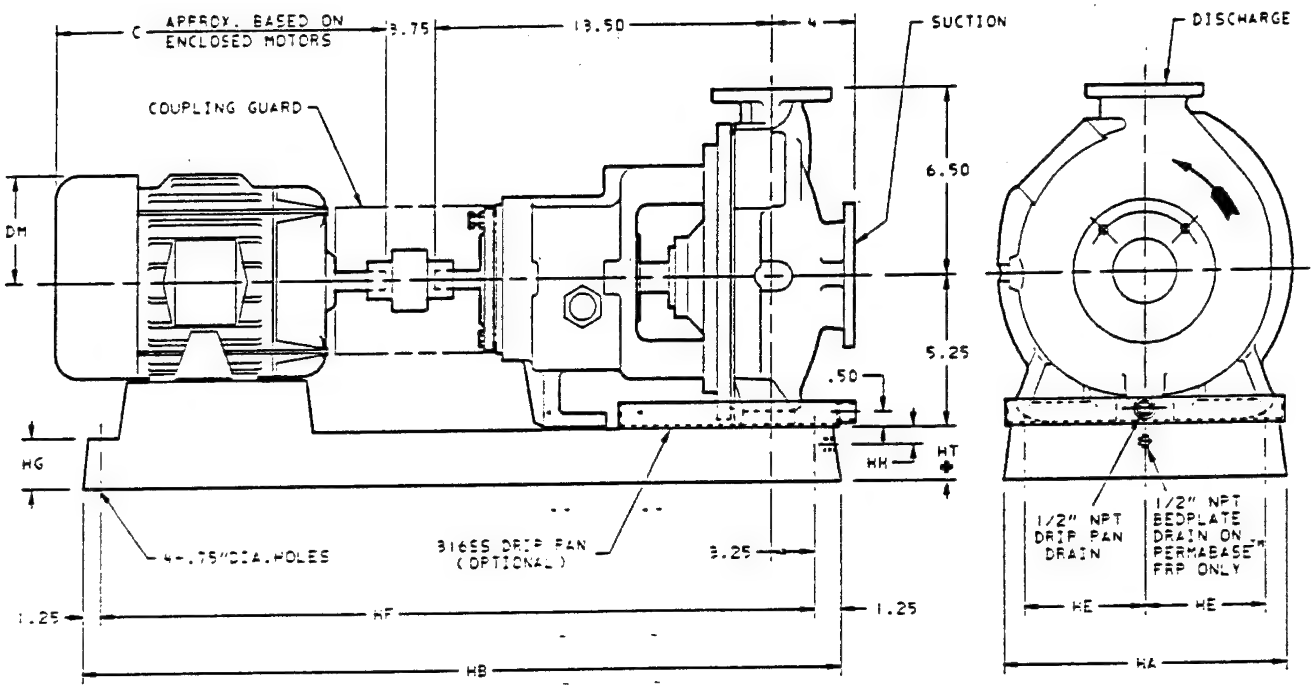
DRAWING A04191A | REVISION 0 | ISSUE 0

FORM NO. 2372

GOULDS PUMPS, INC.

INDUSTRIAL PRODUCTS GROUP
ENGINEERED PRODUCTS DIV.

PUMP OUTLINE DRAWI...
MODEL 3196 STX



	MOTOR DIMENSIONS (TEFC)				
	MOTOR FRAME SIZE	C	DM	WT. INCL. CPLG.	BEDPLATE NUMBER
	56	10.50	3.50	35	1
	143T	12.50	3.50	50	1
	145T	13.50	3.50	55	1
X	182T	14.50	5.00	85	2
	184T	15.50	5.00	100	2
	213T	18.00	6.00	150	2
	215T	19.50	6.00	170	2
	254T	22.50	6.50	245	3
	256T	24.00	6.50	285	3
	284T	25.50	7.50	390	3
	284TS	24.50	7.50	360	3
	286T	27.00	7.50	435	3
	286TS	26.00	7.50	425	3

	PUMP SIZE			
	DISCHARGE SIZE	SUCTION SIZE	CASING CLASS	WEIGHT
X	1	1 1/2	6	84
	1 1/2	3	6	92
	2	3	6	95
	■ 1	1 1/2	8	100
	■ 1 1/2	3	8	108

AVAILABLE OPTIONS	
BEDPLATE	[X] CAST IRON [ ] FABRICATED STEEL [ ] PERMABASE™ FRP W/ 1/2"NP BEDPLATE DRAIN [ ] FLEX MOUNTED STEEL 1 & 2 SEE DRAWING NO. A04193A [ ] Y-BASE™
316SS DRIP PAN	[ ] FURNISHED [X] NOT FURNISHED
FLANGES	[X] 150# ANSI FLAT FACE [ ] 150# ANSI RAISED FACE [ ] 300# ANSI FLAT FACE ■ [ ] 300# ANSI RAISED FACE ■
COUPLING GUARD FURNISHED BY	[X] GOULDS [ ] OTHERS

	BEDPLATE DIMENSIONS													
	NO.	HA	HB	HT			HG			HE	HF	HH	WEIGHT		
				CAST IRON	STEEL	FRP	CAST IRON	STEEL	FRP				CAST IRON	STEEL	FRP
	1	10	35	3.00	2.88	3.19	2.69	2.88	3.00	4.00	32.50	1.19	75	87	22
X	2	12	39	3.25	3.31	3.69	3.06	3.19	3.12	4.50	36.50	1.38	80	102	29
	3	15	46	5.88	5.25	5.94	4.12	3.38	4.00	6.00	43.50	1.44	120	157	52

◆ TOLERANCE IS +.38 -0 FOR CAST IRON BEDPLATE.

■ WHEN 300# FLANGES ARE FURNISHED, DISCHARGE FLANGE WILL BE THREADED, AS FOLLOWS:
1 X 1 1/2 - 8 : 4-5/8-11 UNC-2B
1 1/2 X 3 - 8 : 4-3/4-10 UNC-2B

⊖ WHEN FLEX MOUNTED STEEL BEDPLATE IS REQUIRED FOR MOTOR FRAMES 254T-286TS, SEE DRAWING NO. A03836A

INSTALL FOUNDATION BOLTS IN PIPE SLEEVES. ALLOW FROM .75" TO 1.50" FOR GROUTING. SEE INSTRUCTION BOOK FOR DETAILS.

FOR TAPPED OPENINGS REFER TO DRAWING NO. A04190A

CERTIFIED FOR CONSTRUCTION PURPOSES ONLY WHEN SIGNED.

SIGNATURE ______________________ DATE ________

CUSTOMER. WOODWARD & CLYDE

GOULDS SERIAL NO.

CUSTOMER P.O. NO.

ITEM NO.

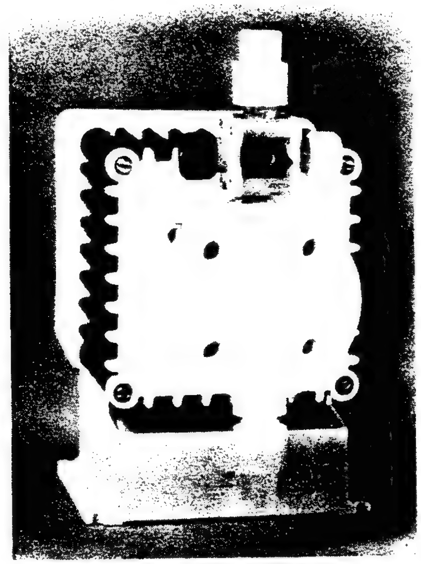
SERVICE. H_2SO_4. INJECTION

ISSUE	DRAWING IS NOT TO SCALE DIMENSIONS IN INCHES WEIGHTS (LBS) ARE APPROXIMATE	DRAWN DJN 4-9-91 APPROVED RAS 6-24-91	DRAWING A04191A	REVISION 0	ISSUE 0

FORM NO. 2372

SERIES B and D
ELECTROMAGNETIC METERING PUMPS

■ *LMI'S ACCURATE, DEPENDABLE SERIES B METERING PUMP— CONTROL PANEL VIEW*



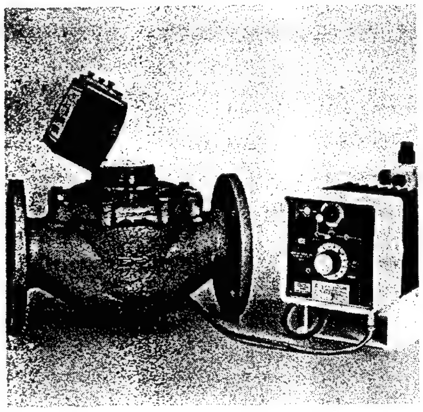
■ *LMI'S TOTALLY ENCLOSED, CORROSION RESISTANT SERIES D METERING PUMP— PUMP HEAD VIEW*

LMI
LIQUID METRONICS DIVISION
MILTON ROY

Bulletin Sec. 1.2 pg. 9000
Replaces pgs. 1000, 1100 and Sec. 1.
pgs. 1000, 1100 and Sec. 2.0 pg. 1100
1417.A 10/87 2A

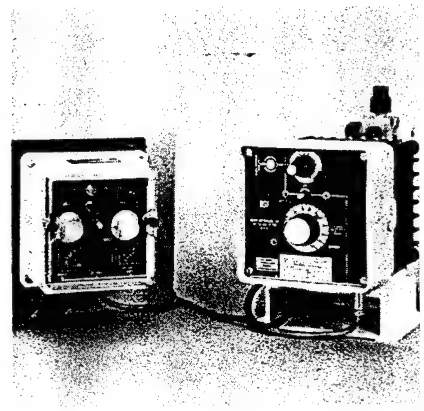
LMI'S SERIES B AND SERIES D METERING PUMPS

for accurate, dependable fluid metering



Series B7 Metering Pump with an LMI FP Series Flowmeter Pulser for proportional fluid metering.

Series B Metering Pump mounted on an LMI 50 gallon ultra-violet resistant polyethylene tank.



Series D7 with an LMI Liquitron, housed in a NEMA 4 enclosure, for instrument responsive control.

In addition to a wide range of control options, LMI's Series B and Series D Metering Pumps offer these advantages:

ELECTROMAGNETICALLY DRIVEN

Solid state encapsulated electronics isolated in compartment opposite liquid end.

No rotating masses such as motors or reduction gears.

Low energy consumption—power used only during discharge portion of each stroke.

INHERENT PRESSURE RELIEF

Should the back pressure exceed the the strength of the magnetic force developed by the power coil, the pump will stop stroking, preventing any damage and eliminating the need for a pressure relief valve.

TOTALLY ENCLOSED, CORROSION RESISTANT

Pumps are enclosed in housings of corrosion-proof glass fiber reinforced polypropylene, protecting the pump from spilled chemical and corrosive atmosphere.

LOW MAINTENANCE

One moving unit, the armature-diaphragm assembly. No lubrication required.

Modular construction provides easy replacement of components and major assemblies.

LOCAL AVAILABILITY, LOCAL SERVICE AND REPAIR

Provided through LMI's international network of distributors and authorized repair centers.

LMI'S UNIQUE 4 FUNCTION VALVE

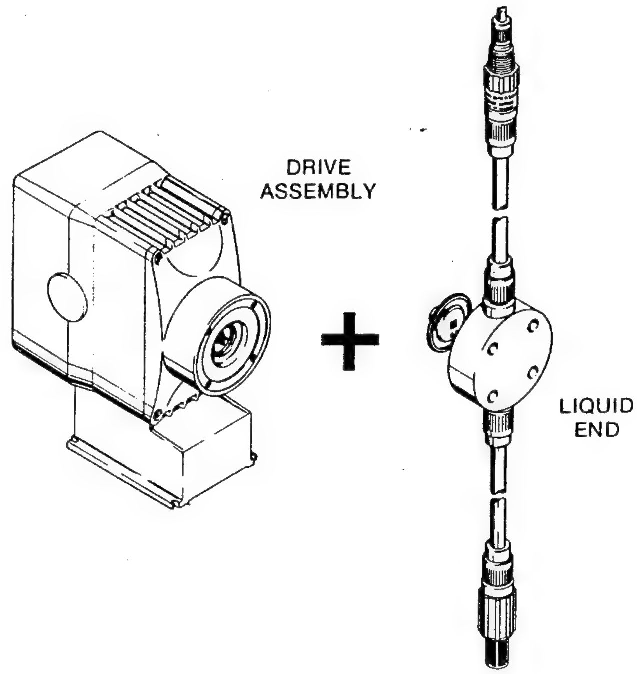
Provides the following added protection:

1. **Anti-syphon protection**—The positive diaphragm type feature of LMI's four function valve makes it possible to meter liquids "down-hill," even into the suction side of a well or circulating pump.
2. **Back pressure function**—Permits metering into atmospheric discharge (open tank) without over pumping due to discharge velocity.
3. **Priming-line pressure release**—Makes depressurizing the discharge line possible without loosening tubing or fittings and allows priming of the pump while it is connected to the pressurized line.
4. **Pressure relief function**—Although not required for electromagnetic pumps due to the inherent pressure relief, this added feature is designed to open at approximately 175 psi.

SELECTING YOUR PUMP

LMI chemical metering pumps are made by combining two major components: the drive assembly, which provides the power for the pumping action, and the liquid end, which is the area through which the pumped solution flows.

To arrive at the complete model number for your Series B or D metering pump, combine the drive assembly number (i.e. B74), the voltage code required (i.e. 1), and the liquid end chosen (i.e. 12S). These combined numbers are your final pump part number (B741-12S).



SELECTING THE DRIVE ASSEMBLY

To choose the correct combination for your application, begin by selecting the drive assembly with the control option, voltage code and output specifications to match your requirements. Listed below and on the following pages are the available control options, voltage codes and output specifications for Series B and Series D metering pumps.

1. CONTROL OPTIONS

DUAL MANUAL CONTROL—SERIES B1, D1

These pumps offer the versatility of independently adjustable stroke length and stroke frequency, allowing dual manual control of pump output.

INSTRUMENT RESPONSIVE CONTROL—SERIES B4, D4

Series B4 and D4 pumps will respond directly and proportionally to a 4-20 mA DC instrument signal through the built in signal receiver. At 4mA DC input signal, pump output is zero, with pump output increasing proportionally as input signal increases.

*AUTOMATIC CONTROL—SERIES B7, D7**

These pumps respond to any dry switch closure, providing automatic stroke frequency control and proportional feeding. A mode switch allows you to choose this automatic stroke frequency control or dual manual control. Adjustable electronic pressure control is another unique, standard feature on these pump models.

*Series BE and DE pumps offer the automatic stroke frequency control feature of the B7 and D7 series with a spring loaded selector switch which must be held in place by the operator for the pump to function in the manual control mode. When switch is released, the pump stops, eliminating the possibility that the pump can be left in manual control mode on installations requiring automatically paced chemical feed.

2. OUTPUT SPECIFICATIONS

SERIES	GALLONS PER HOUR		LITERS PER HOUR		mL OR CC PER MIN.		OUTPUT PER STROKE		MAX INJECTION PRESSURE
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
B11, B71	.008	1.6	.03	6	0.5	100	1.0	1.0	150 PSI (10.3 Bar)
BE2, B12, B72	.012	2.5	.05	9.5	.79	158	.16	1.58	100 PSI (6.9 Bar)
BE3, B13, B73	.022	4.5	.085	17.0	1.42	284	.28	2.84	50 PSI (3.4 Bar)
B14, B74, BE7	.04	7.0	.13	26.5	2.21	442	.44	4.42	30 PSI (2.07 Bar)
B41*	0.	1.6	0.	6.0	0.	100	.1	1.0	150 PSI (10.3 Bar)
B42*	0.	2.5	0.	9.5	0.	158	.16	1.58	100 PSI (6.9 Bar)
B43*	0.	4.5	0.	17.0	0.	284	.28	2.84	50 PSI (3.4 Bar)
B44*	0.	7.0	0.	26.5	0.	442	.44	4.42	30 PSI (2.07 Bar)
D11, D71	.012	2.5	.05	9.5	.79	158	.21	2.10	150 PSI (10.3 Bar)
DE2, D12, D72	.02	4.0	.76	15.2	1.28	252	.34	3.36	100 PSI (6.9 Bar)
DE3, D13, D73	.04	8.0	.15	30.3	2.51	505	.67	6.73	60 PSI (3.4 Bar)
DE4, D14, D74	.1	20.0	.38	76.0	6.3	1260	1.68	16.8	20 PSI (2.07 Bar)
D41*	0.	2.5	0.	9.5	0.	158	.1	1.02	150 PSI (10.3 Bar)
D42*	0.	4.0	0.	15.2	0.	253	.32	3.16	100 PSI (6.9 Bar)
D43*	0.	8.0	0.	30.3	0.	504	.63	6.3	60 PSI (3.5 Bar)
D44*	0.	20.0	0.	76.0	0.	1262	1.6	15.8	20 PSI (2.07)

*Series B4 and D4 pumps operate from a 4-20 mA signal source. Incoming signal automatically controls pump output from zero to maximum.

3. VOLTAGE CODES

The final digit of each drive assembly number designates both voltage and power cord/plug type. When ordering please indicate desired voltage by inserting one of the following digits in this position.

[1] 115 VAC
[2] 230 VAC
[3] 220 - 240 VAC, DIN Plug
[5] 240 - 250 VAC, British (UK) Plug
[6] 240 - 250 VAC, Aust./N.Z. Plug
[7] 220 VAC, Swiss Plug

You should now have a complete Drive Assembly part number, such as B721, where B7 indicates the control option you chose in step 1, 2 indicates the output range you require from step 2, and 1 indicates the voltage code you require from step 3.

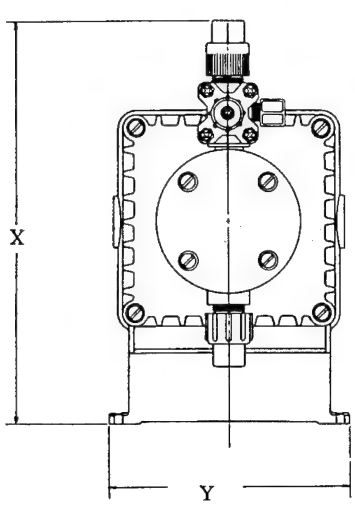
ADDITIONAL SPECIFICATIONS

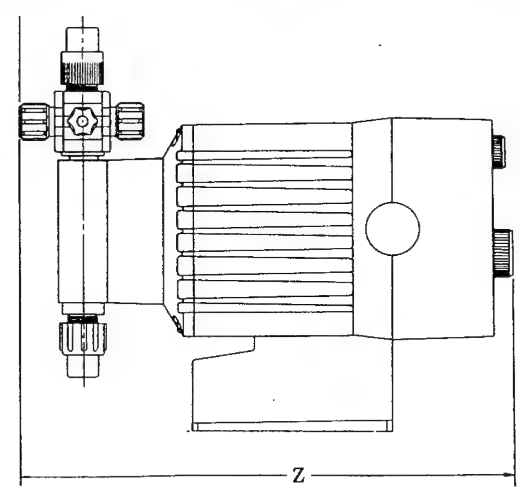
SERIES	PEAK INPUT POWER (WATTS)	AVERAGE INPUT POWER (WATTS @ MAX SPEED)	STROKE LENGTH ADJUSTABLE (0-100%) RECOMMENDED MIN.	STROKE FREQUENCY ADJUSTABLE (STROKES PER MINUTE)
B11, B71	248	29	15%	5 TO 100
B12, B13, B14	248	29	10%	5 TO 100
B41, B42, B43, B44	248	29	10%	0 TO 100
B72, B73, B74	248	29	10%	5 TO 100
D10, D11, D12, D13, D14	381	33	10%	3.75 TO 75
D40, D41, D42, D43, D44	381	33	10%	0 TO 75
D70, D71, D72, D73, D74	381	33	10%	3.75 TO 75

VOLTAGE: 115 VAC, 50/60 Hz, SINGLE PHASE
230-250 VAC, 50/60 Hz, SINGLE PHASE

DIMENSIONS

SERIES	LENGTH (Z) Inches (mm) MAX	WIDTH (Y) Inches (mm) MAX	HEIGHT (X) Inches (mm) MAX	SHIPPING WEIGHT LBS (Kg)
B1, B7	10.5 (267)	5.72 (146)	8 (203)	15 (6.9)
B4	10.75 (273)	5.72 (146)	8 (203)	15 (6.9)
D1, D7	11.625 (296)	5.72 (146)	9.25 (235)	19 (8.7)
D41, D42	10.75 (273)	5.72 (146)	9.25 (235)	19 (8.7)
D43	11.0 (280)	5.72 (146)	9.25 (235)	19 (8.7)
D44	11.70 (298)	5.72 (146)	9.25 (235)	19 (8.7)





SELECTING THE LIQUID HANDLING ASSEMBLY

Once you have selected the proper drive assembly, you must then select a liquid end compatible with both the drive assembly and the chemical you are pumping. Listed below are Series B and D drive assemblies and liquid ends compatible with each.

LIQUID END NO.	B11, B12, B41, B42, B71, B72	B13, B43, B73	B14, B44, B74	D10, D40, D70	D11, D41, D71	D12, D42, D72	D13, D43, D73	D14, D44, D74	COMMON USE CATEGORIES ++
11S+			*						Alkalies, Dilute Acids
12S+			*						Acids
15S+			*						Bioacids, Solvents, Alkalies, Acids
20HV							*		High Viscosity Materials, Polymers
20S+							*		Alkalies, Dilute Acids
24							*		Acids
25HV							*		High Viscosity Materials, Polymers
25P							*		Bioacids, Solvents, Alkalies, Acids
25T							*		Bioacids, Solvents, Alkalies, Acids
26S+							*		Acids
27							*		Solvents, High Temperature
30								*	Alkalies, Dilute Acids
34								*	Acids
35P								*	Bioacids, Solvents, Alkalies, Acids
35T								*	Bioacids, Solvents, Alkalies, Acids
36								*	Acids
37								*	Solvents, High Temperature
71FS					*	*			Hydrofluorosilic Acid
71S		*			*	*			Alkalies, Dilute Acids
71T		*			*	*			Alkalies, Dilute Acids
72S		*			*	*			Acids
72T		*			*	*			Acids
74		*			*	*			Acids
75HV		*				*			High Viscosity Materials, Polymers
75S		*			*	*			Bioacids, Solvents, Alkalies, Acids
76		*				*			High Viscosity Materials, Polymers
77		*			*	*			Solvents, High Temperature
85HV	*								High Viscosity Materials, Polymers
86	*								High Viscosity Materials, Polymers
91FS	*								Hydrofluorosilic Acid
91S	*								Alkalies, Dilute Acids
91T	*								Alkalies, Dilute Acids
92S	*								Acids
92T	*								Acids
94	*			*					Acids
95S	*								Acids
95T	*								Bioacids, Solvents, Alkalies, Acids
97	*			*					Solvents, High Temperature

+ These liquid handling assemblies are also available without LMI's unique 4-Function valve. To order a liquid handling assembly without this option, drop the 'S' at the end of the liquid handling number.

+ + For descriptive purposes only. This is not a recommendation of suitability for a specific chemical solution. Please consult your local LMI distributor for specific information.

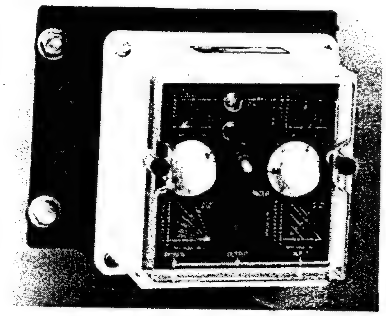
Once you have determined which liquid ends are compatible with the chosen drive assembly, refer to the table below and choose the liquid end in that grouping which is constructed of materials most compatible with the chemical you are pumping.

LIQUID END NO.	MATERIALS OF CONSTRUCTION					CONNECTIONS	ACCESSORY
	HEAD	FITTINGS	VALVE BALLS	LIQUIFRAM	SEAL RINGS		
11S	Acrylic	PVC	Ceramic	Teflon Face	Polyprel™	Tubing .5″	4FV
12S	PVC	PVC	Ceramic	Teflon Face	Polyprel™	Tubing .5″	4FV
15S	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	4FV
20HV	Acrylic	Polypropylene	Ceramic	Teflon Face	Hypalon	Tubing .5″ Discharge .938″ Suction	
20S	Acrylic	PVC	Ceramic	Teflon Face	Hypalon	Tubing .5″	4FV
24	PVC	PVC	Ceramic	Teflon Face	Teflon	Pipe 1/2″ NPT M	
25HV	Polypropylene	316 S.S.	316 S.S.	Teflon Face	Teflon	Tubing .5″ Discharge .938″ Suction	
25P	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Pipe 1/2″ NPT M	
25T	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	
26S	PVC	PVC	Ceramic	Teflon Face	Viton	Tubing .5″	4FV
27	316 S.S.	316 S.S.	316 S.S.	Teflon Face	Teflon	Pipe 1/2″ NPT M	
30	Acrylic	PVC	Ceramic	Teflon Face	Teflon	Tubing .5″	
34	PVC	PVC	Ceramic	Teflon Face	Teflon	Pipe 1/2″ NPT M	
35P	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Pipe 1/2″ NPT M	
35T	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	
36	PVC	PVC	Ceramic	Teflon Face	Teflon	Tubing .5″	
37	316 S.S.	316 S.S.	316 S.S.	Teflon Face	Teflon	Pipe 1/2″ NPT M	
71FS	Acrylic	PVC	Teflon	Teflon Face	Hypalon	Tubing .5″	4FV
71S	Acrylic	PVC	Ceramic	Teflon Face	Teflon	Tubing .5″	4FV
71T	Acrylic	PVC	Ceramic	Teflon Face	Teflon	Tubing .5″	
72S	PVC	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	4FV
72T	PVC	PVC	Ceramic	Teflon Face	Teflon	Tubing .5″	
74	PVC	PVC	Ceramic	Teflon Face	Teflon	Pipe 1/4″ NPT M	
75HV	Polypropylene	316 S.S.	316 S.S.	Teflon Face	Teflon	Tubing .5″ Discharge .938″ Suction	
75S	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	4FV
75T	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .5″	
76	Acrylic	Polypropylene	Ceramic	Teflon Face	Hypalon	Tubing .5″ Discharge .938″ Suction	
77	316 S.S.	316 S.S.	316 S.S.	Teflon Face	Teflon	Pipe 1/4″ NPT F	
85HV	Polypropylene	316 S.S.	316 S.S.	Teflon Face	Teflon	Tubing .5″ Discharge .938″ Suction	
86	Acrylic	Polypropylene	Ceramic	Teflon Face	Hypalon	Tubing .5″ Discharge .938″ Suction	
91FS	Acrylic	PVC	Teflon	Teflon Face	Hypalon	Tubing .375″	4FV
91S	Acrylic	PVC	Ceramic	Teflon Face	Teflon	Tubing .375″	4FV
91T	Acrylic	PVC	Ceramic	Teflon Face	Teflon	Tubing .375″	
92S	PVC	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .375″	4FV
92T	PVC	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .375″	
94	PVC	PVC	Ceramic	Teflon Face	Teflon	Pipe 1/4″ NPT F	
95S	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .375″	4FV
95T	Polypropylene	Polypropylene	Ceramic	Teflon Face	Teflon	Tubing .375″	
97	316 S.S.	316 S.S.	316 S.S.	Teflon Face	Teflon	Pipe 1/4″ NPT F	

ACCESSORIES

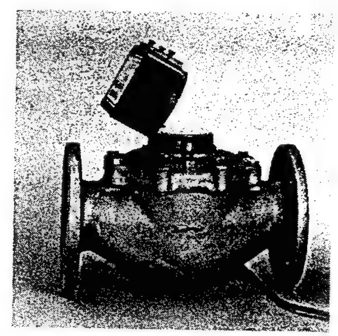
LMI offers a full line of chemical metering pump accessories to complete your installation including:

LIQUITRON



For use with Series B7 or D7 metering pumps to make stroke frequency vary in response to analog instrument signal. Available in single or dual and twin channel models.

FLOWMETER-PULSERS



For use with Series BE, DE, B7 and D7 metering pumps for chemical treatment proportional to water flow. Programmable for wide ratio range, with flow rates from 1 to 650 US GPM.

For more information on these and LMI's complete line of metering pumps and accessories, please contact your local distributor.

LIQUID METRONICS DIVISION, MILTON ROY

19 Craig Road, Acton, MA 01720-5495 • TEL (508) 263-9800 • TLX 95-1781 • FAX (508) 264-9172

All prices quoted FOB Acton, MA.
Prices and specifications subject to change without notice.

Printed in U.S.A.

BASIN F STORAGE TANK 102 DECONTAMINATION
ROCKY MOUNTAIN ARSENAL, COLORADO

CONFIRMATION NOTICE NO. _______

Woodward-Clyde Project No. 89C114MM
File No. 23016A (1.1)

Date: 5-21-92

Participants:

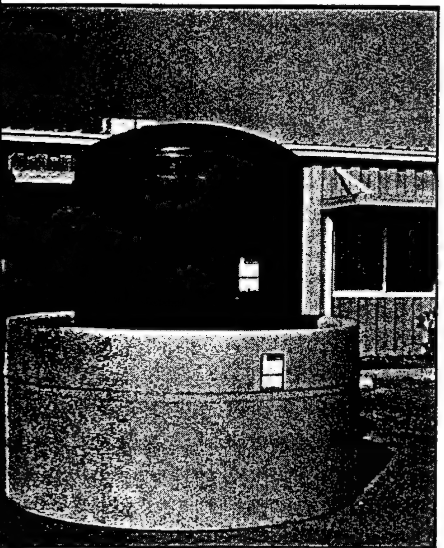
(To): Poly Cal Plastics, Inc.

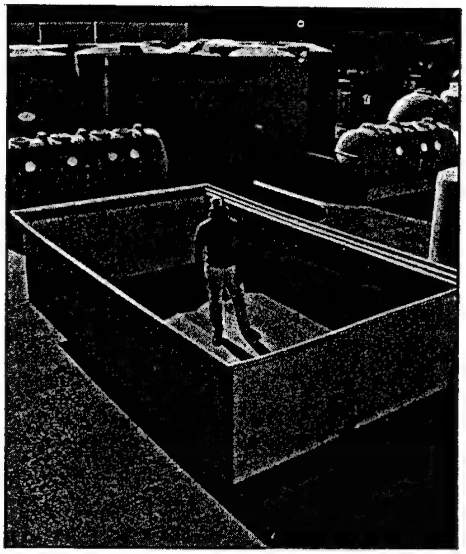
(From): Joseph Scott/WCC

(Others):

Subject and Conclusion: Price quote for plastic tanks. Called to obtain a price quote for primary sulfuric acid tank and secondary containment tank for acid tank. Acid tank: 110 gallon capacity closed top cross-linked polyethylene tank model # 089U, 30" diameter and 43" height $258/ea. Secondary containment tank: 225 gallon nominal capacity open top cross-linked polyethylene tank model # 074XL, 41" to 47" diameter 41" height $233/ea. 1/2" stainless steel couplings for outlets on acid tank model # 562 $33/ea. All prices FOB French Camp, CA (near Stockton). Local representative is Tanks Plus, Inc. 457-3685.

OVERFLOW CONTAINMENT TANK





Primary Tanks

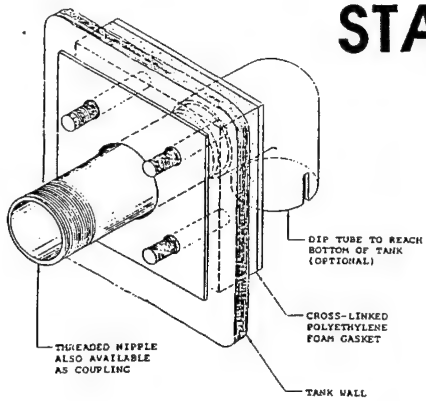
Stock #	Gallons	Diameter	Height
01U	55	23"	37½"
089U	110	30"	43"
02U	150	31" to 37"	45"
03U	200	37"	4'7¾"
060U	235	41" to 49"	45"
04U	375	4'	4'9"
05U	500	4'	6'¾"
057U	600	58½" to 72½"	48"
SP078U	630	4'	7'8¼"
06U	700	5'1"	5'5"
SP076U	710	4'	8'3¾"
023U	1050	5'1"	8'2½"
07U	1100	7'5"	4'2"
033U	1350	74" to 90"	64"
077U	1400	7'5"	5'2"
SP017U	1500	5'1"	11'6"
08U	1600	7'8"	5'
SP084U	1850	6'¾"	9'6"
09U	2000	7'5"	7'2"
SP086U	2400	6'	12'8"
010U	2500	7'10"	8'1"
SP079U	2800	9'11"	6'
SP087U	3050	6'	15'7"
012U	3100	7'7"	10'2"
SP013U	4000	8'	11'6"
SP061U	4200	9'11"	8'4"
SP014U	5000	9'11"	9'10"
SP067U	6200	8'	17'6"
SP015U	6500	9'11"	11'10"
SP080U	7100	9'11"	13"
SP054U	8200	9'11"	15'

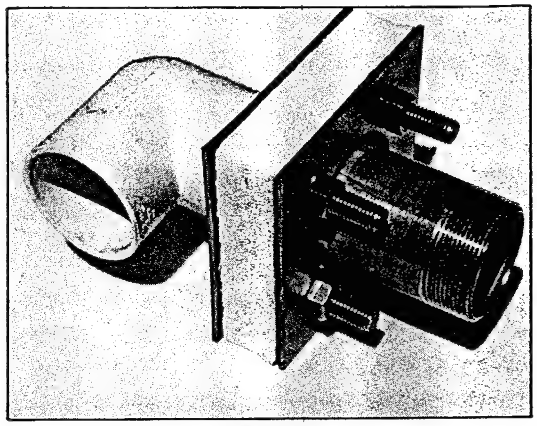
All tanks carry a 6 year prorated warranty.

Open Top Containment Tanks

Stock #	Gallons	Diameter	Gallons Required	Height
068XL	70	30"	69	2' (cut)
074XL	225	41" to 47"	137	41"
074XL	225	41" to 47"	187	41"
036XL	350	4'	250	4'
058XL	500	58½" to 72½"	294	42"
058XL	500	58½" to 72½"	469	42"
038XL	670	61"	625	4'9"
041XL	1300	7'8"	750	3'9"
SP081XL	1250	6'¾"	788	6'
SP081XL	890	6'¾"	875	4'2" (cut)
039XL	1010	5'1"	887	7'5"
041XL	1300	7'8"	1312	3'9"
SP096XL	1400	9'11"	1375	2'4" (cut)
SP096XL	1750	9'11"	1687	2'10" (cut)
SP096XL	1750	9'11"	1750	3' (cut)
SP069XL	2750	8'	1825	7'10"
SP096XL	2000	9'11"	2000	3'5" (cut)
SP069XL	2750	8'	2375	7'10"
SP071XL	3750	9'11"	2500	6'11"
043XL	3000	7'7"	3000	9'2"
SP071XL	3750	9'11"	3125	6'11"
SP049XL	3500	11'11"	3500	4'2" (cut)
SP059XL	4000	8'	3812	11'4"
SP071XL	3750	9'11"	3875	6'11"
SP028XL	4800	9'11"	5000	8'10"
SP055XL	5250	11'11"	5250	6'3" (cut)
SP055XL	6600	11'11"	6250	8'
SP056XL	8000	9'11"	7750	14'6"
SP030XL	8500	11'11"	8125	10'4"
SP030XL	8500	11'11"	8875	10'4"
SP031XL	10000	11'11"	10250	12'8"
SP770XL	5750	14'	5980	5'
SP771XL	8050	14'	8050	7'
SP772XL	10360	14'	10580	9'
SP773XL	12660	14'	12765	11'
SP774XL	14965	14'	14950	13'

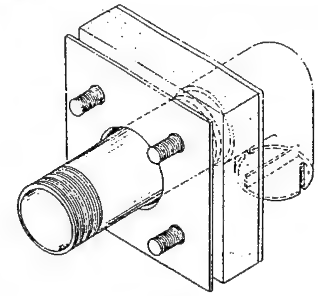
STAINLESS STEEL FITTINGS





#525

2" DIA. 4 [illegible] FULL NIPPLE (SHOWN w/DIP-



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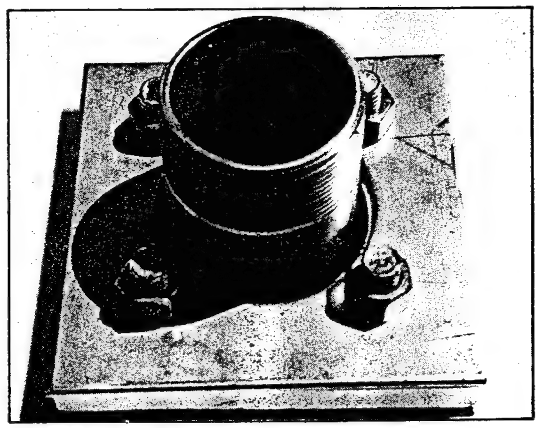
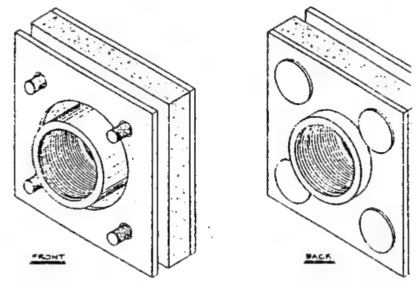
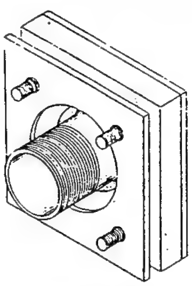


1" DIA. 4 BOLT FULL COUPLING



#B521

1" DIA. 4 BOLT HALF NIPPLE



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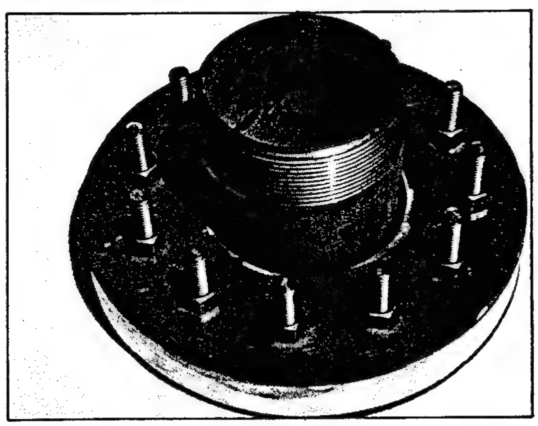
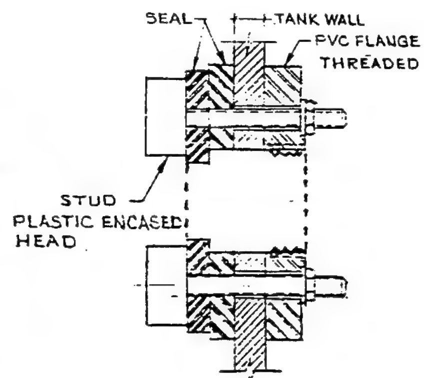


#SP552

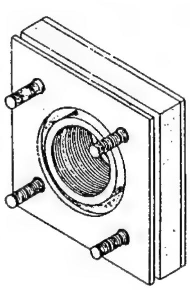
TYPICAL

PVC Flange Fitting, S.S. Studs
Plastic encased heads.



SP515

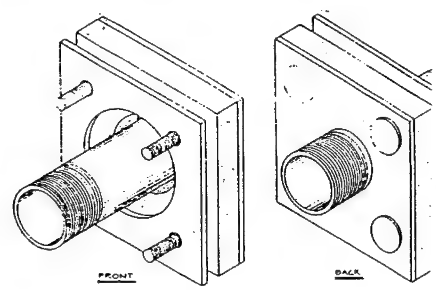
DIA. 4 BOLT HALF COUPLING



#567

#567

1" DIA. 4 BOLT FULL NIPPLE



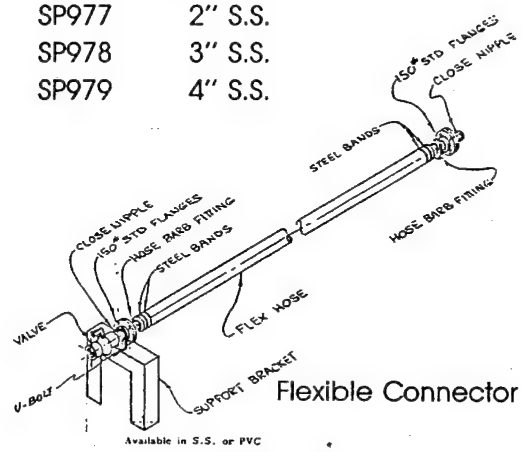
#A521

STAINLESS STEEL FITTINGS W/GASKETS

Stock No.	Size	Description
518*	3/8"	3-Bolt-Full Coupling
561*	½"	3-Bolt-Full Coupling
562**	½"	4-Bolt-½ Nipple
519*	¾"	3-Bolt-Full Coupling
A519**	¾"	4-Bolt-½ Nipple
564*	¾"	4-Bolt-Full Coupling
520**	¾"	4-Bolt-Full Nipple
A520**	¾"	3-Bolt-½ Nipple
521**	1"	4-Bolt-½ Nipple
A521**	1"	4-Bolt-Full Nipple
B521*	1"	4-Bolt-Full Coupling
522**	1½"	4-Bolt-½ Nipple
523**	1½"	4-Bolt-Full Nipple
A523*	1½"	4-Bolt-Full Coupling
524**	2"	4-Bolt-½ Nipple - 316 S.S.
525**	2"	4-Bolt-Full Nipple 2/Dip Tube - 316 S.S.
567*	2"	4-Bolt-½ Coupling
568*	2"	4-Bolt-Full Coupling
527**	3"	8-Bolt-½ Nipple
A527**	3"	8-Bolt-Full Nipple w/Dip Tube
SP528**	3"	11-Bolt-½ Coupling
SPA528**	3"	11-Bolt-Full Coupling w/Dip Tube
SP552**	4"	11-Bolt-½ Nipple
SPA552**	4"	11-Bolt-Full Nipple w/Dip Tube
SP573*	4"	11-Bolt-½ Coupling
SP574*	4"	11-Bolt-Full Coupling
SP576**	6"	11-Bolt-½ Nipple
SP577**	6"	11-Bolt-Full Nipple
SP580**	8"	½ Nipple
SP581**	8"	Full Nipple
SP583**	2"	S.S. Vortex Fitting
SP584**	3"	S.S. Vortex Fitting
SP585**	1½"	S.S. Sparge Tube and Fitting
SP586**	2"	S.S. Sparge Tube and Fitting
SP598	2"	S.S. Relief Valve DOT Tank
SP597	3¼" x 3¼"	Stainless Patch for Small Four Bolt Pattern
SP596	5"x5"	Stainless Patch for Large Four Bolt Pattern
SP595	7"x7"	Stainless Patch for Eight Bolt Pattern

FLEXIBLE CONNECTORS

Stock No.	Description
SP975	1" S.S.
SP976	1½" S.S.
SP977	2" S.S.
SP978	3" S.S.
SP979	4" S.S.



Flexible Connector

SPECIAL FITTINGS

Stock No.	Size	Description
SP599	2"	PVC Relief Valve DOT Tank
SP590**	2"	Block Style with S.S. Studs
SP591**	2"	Block Style with Hasteloy Studs
SP591C**	2"	Block Style with Hasteloy Studs and longer bolts
SP514**	1½"	PVC Flange fittings, S.S. Studs plastic encased heads
SP515**	2"	PVC Flange fittings, S.S. Studs plastic encased heads
SP516**	3"	PVC Flange fittings, S.S. Studs, plastic encased heads
SP539**	1½"	PVC Flange fittings, Hasteloy Studs, plastic encased heads
SP540**	2"	PVC Flange fittings, Hasteloy Studs, plastic encased heads
SP541**	3"	PVC Flange fittings, Hasteloy Studs, plastic encased heads

GASKET MATERIAL

SP565	½"x4'x4'	Polyethylene Foam Gasket
SP566	1¼"x4'x4'	Polyethylene Foam Gasket

*FEMALE
**MALE

All Stainless Steel Fittings can be made from mild steel on special order. If longer bolts are necessary, place C- beside the stock number.

Be certain to check compatibility of product with fittings.

BASIN F STORAGE TANK 102 DECONTAMINATION
ROCKY MOUNTAIN ARSENAL, COLORADO

CONFIRMATION NOTICE NO. _______

Woodward-Clyde Project No. 89C114MM
File No. 23016A (1.1)

Date: 5-14-92

Participants:

(To): Great Western Chemical Company

(From): Joseph Scott/WCC

(Others): ____________________

Subject and Conclusion: Availability and Cost for Sulfuric Acid.

I called this Denver area chemical supplier to inquire what concentrations of sulfuric acid they supply in 55-gallon drums and the cost. They stock 50% sulfuric acid in 55-gallon drums. The cost for purchase of one drum is $0.405/lb or approximately $260/drum. The cost for purchase of two drums is $0.291/lb or approximately $186/drum. A $40 deposit is required on each returnable drum.

BASIN F STORAGE TANK 102 DECONTAMINATION
ROCKY MOUNTAIN ARSENAL, COLORADO

CONFIRMATION NOTICE NO. _______

Woodward-Clyde   Project No. 89C114MM
                  File No. 23016A   (1.1   )

Date: 5-11-92

Participants:

(To): Steve Wood/Calgon Carbon Corporation

(From): Joseph Scott/WCC

(Others): ________________

Subject and Conclusion: Granular Activated Adsorption Units for Vent Gas Treatment. I called to obtain design cost information on the various GAC units Steve had sent me information on. I had received telefax information on four different types of units Calgon markets.

1) High Flow Vent Sorb Unit. Contains 1,000 lbs GAC and maximum air flow is 1100 cfm at 15" water pressure loss. Unit sells for $8,500 including GAC and is not available as rental. Return of GAC to Calgon for thermal regeneration and disposal would be $1.50/lb including freight.

2) Vapor-Pac Service Unit. Contains 1,800 lbs GAC and maximum air flow is 800 cfm at 10" water pressure loss. Would likely require two units to treat 1,100 cfm flow. Unit

is not sold. Rental would be $6,500 for two months for each unit. This includes freight to and from site and disposal of spent GAC.

3) Vapor Pac 10 Unit. Contains 12,000 lbs GAC and maximum air flow is 10,000 cfm at 10" water pressure drop. Would likely require two units for 13,000 cfm flow. Unit is not sold. Rental would be $25,500 for two months for each unit. This includes freight to and from site and disposal of spent GAC.

4) 12' Dual Bed Adsorber Odor Control System. Contains 12,500 lbs GAC and at 13,000 cfm pressure loss is 6" water. System is not available for rental and would have to be fabricated for job. Purchase cost would be $50,000 including GAC. Return of GAC to Calgon for thermal regeneration and disposal would be $1.50/lb. including freight.

Steve recommended the Vapor Pac units for the 1,100 cfm system and the Vapor Pac 10 units for the 13,000 cfm system. The recommended type of GAC would be BPL 4x10 or BPL 6x16. There would be a one time charge of $4,500 for analysis of GAC for acceptance of RCRA GAC for regeneration and disposal.

CALGON

CALGON CARBON CORPORATION

2121 S. El Camino Real San Mateo, CA 94403-1801

Attention: JOE SCOTT

Date: 5-8-92

Company: WOODWARD CLYDE

Phone: (303) 740-3917

From: STEVE WOOD

Fax #: (303) 694-3946

Subject: CARBON SERVICE UNITS

No. Of Pages: 14

Comments:

JOE —

PLEASE FIND ENCLOSED THE INFORMATION ON THE VAPOR PAC UNIT. THE SMALL UNIT CAN HANDLE THE AIR FLOW AND HAS A TOTAL PRICE FOR THE TWO (2) MONTH PROJECT OF $14,500.00 EA. ADDITIONAL UNITS WOULD BE EXTRA.

ON SECOND THOUGHT, I BELIEVE THE VAPOR PAC 10 UNIT MIGHT BE A BETTER CHOICE, EVEN IF YOU HAVE TO RUN TWO (2) UNITS IN PARALLEL. THE VAPOR PAC 10 CONTAINS 12,500 lbs OF CARBON AND CAN HANDLE 70,000 CFM. THE UNITS ARE MORE READILY AVAILABLE AND THE FEES ARE A LOT LESS. THEY ARE $25,500 EA. FOR TWO (2) MONTHS. BOTH THE UNITS INCLUDE SPENT CARBON HANDLING WHEN THE JOB IS COMPLETE, PENDING SPENT CARBON ACCEPTANCE TESTING.

THERE IS A ONE TIME SPENT CARBON ACCEPTANCE TESTING FEE FOR RCRA CARBON OF $4500.00

PLEASE GIVE ME A CALL SHOULD YOU HAVE ADDITIONAL QUESTIONS. REGARDS

Steve Wood

PLEASE CALL IF YOU DO NOT RECEIVE THE TOTAL NUMBER OF PAGES

Phone # (415) 572-9111 Fax # (415)574-4466

CALGON
CALGON CARBON CORPORATION

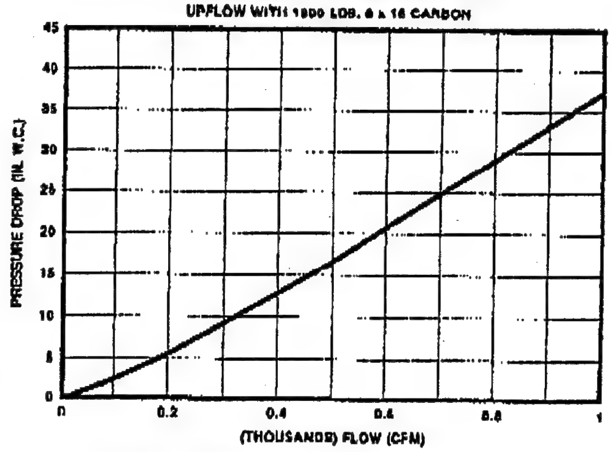
VAPOR-PAC SERVICE UNIT

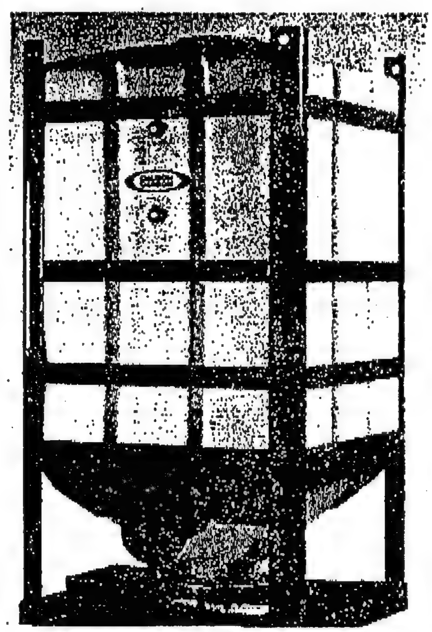
Calgon Carbon Vapor-Pac Service Units are designed to remove volatile organic compounds from various vapor streams using granular activated carbon adsorption. The units are particularly suited for short term projects, or for low volume applications where VOC concentrations are relatively high. Common applications include control of industrial process vents, air stripper off-gases, or emissions of organic compounds from in-situ treatment of contaminated soils.

A unique feature of the Vapor-Pac unit is that it serves as both a shipping container and an adsorber, which is easily transported and installed. When the carbon is spent, the unit is simply disconnected and returned to Calgon Carbon for carbon reactivation — provided the spent carbon meets Calgon Carbon's acceptance criteria.

Each Vapor-Pac Service Unit contains 1800 lbs. of vapor phase granular activated carbon and is capable of handling flows up to 1000 cfm. Vapor-Pacs may be operated in series or parallel mode. Your Calgon Carbon representative is available to assist you in evaluating the suitability of the Vapor-Pac Service for your particular application.

VAPOR-PAC UNIT PRESSURE DROP
UPFLOW WITH 1800 LBS. 4 x 10 CARBON





FEATURES

- Allows for ease of installation
- Constructed of corrosion resistant materials
- Designed for upflow operation in series or parallel mode
- Eliminates on-site carbon handling
- Minimizes spent carbon disposal problems
- Provides convenient carbon sampling device

SPECIFICATIONS

Vessel Dimensions:	44¼" x 44¼" x 89⁵/₈"
Inlet & Discharge Connections:	6" Ø PS 15-69 Duct Flanges
Carbon Volume:	60 cu. ft. (1800 lbs.)
Shipping Weight:	Virgin - 2200 lbs. Spent - 4000 lbs.
Temperature Rating:	150°F max.
Static Pressure rating above carbon level:	20" W.C. max.
Vacuum Pressure rating above carbon level	2" W.C. max.

All units shipped F.O.B., Pittsburgh, Pennsylvania

MATERIALS OF CONSTRUCTION

Vessel:	Polyethylene
Frame:	Carbon Steel coated with Sherwin Williams Tile Clad II
Inlet Flanges, Elbow, Septa:	PVC
Discharge Flange:	Polyethylene
Fasteners & Bottom Valve Support Plate:	316 Stainless Steel
Sample Fittings & Sample Canister:	PVC

CAUTION

Wet activated carbon preferentially removes oxygen from the air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low-oxygen spaces should be followed, including all applicable Federal and State requirements.

For information regarding human and environmental exposure, call (412) 787-6700 and request to speak to Regulatory and Trade Affairs.

CALGON
CALGON CARBON CORPORATION

VAPOR PAC SERVICE FOR VOC CONTROL

Calgon Carbon's Vapor Pac Service meets industrial needs for cost-effective removal of volatile organic compounds (VOCs) at air emission sources.

The Vapor Pac Service features a small, easily transportable adsorber which contains 1,800 pounds of activated carbon. The adsorber can handle air flows up to 1,000 cfm.

Designed to remove both toxic and non-toxic VOCs, the adsorption system is especially useful for short-term projects and for treatment of low volume flows that contain low to moderate VOC concentrations. Common applications include VOC removal from process vents, soil remediation vents, and air stripper off-gases.

To accommodate a wide variety of process conditions, Vapor Pac adsorbers are available in two basic designs: a polyethylene model that offers excellent corrosion-resistance, and a stainless steel model than can withstand higher temperatures, and slight pressure or vacuum conditions.

Calgon Carbon provides the adsorber, carbon, spent carbon handling and carbon reactivation (after the carbon meets the company's acceptance criteria) as part of the Vapor Pac Service. Ductwork and fans are the only equipment requiring a capital expenditure by the user.

When carbon becomes saturated with VOCs, the system is replaced with another adsorber containing fresh carbon.

By utilizing this unique service, users can generally achieve VOC removal and regulatory compliance objectives, minimize operating costs, and eliminate maintenance costs* (as the equipment is owned and maintained by Calgon Carbon). Furthermore, because organic compounds are safely destroyed through the carbon reactivation process, costs and regulations typically associated with waste disposal can be eliminated.

Please contact a Calgon Carbon Technical Sales Representative to learn more about the advantages of the Vapor Pac Service for your specific VOC control needs.

**Damage to Vapor Pac Unit caused by negligence or misapplication is the responsibility of the user.*

FEATURES AND BENEFITS OF VAPOR PAC SERVICE

- Adsorbers are specifically designed for ease of installation and operation.
- Adsorbers are available in plastic (polyethylene) and metal (stainless steel) construction to accommodate a wide variety of applications.
- System can be operated in series or parallel mode or a combination of both modes to handle a variety of flows and concentrations.
- System exchange eliminates on-site carbon handling.
- Recycling of spent carbon eliminates disposal problems.
- Capital expenditure is eliminated since Calgon Carbon Corporation owns and maintains equipment.

VAPOR PAC (PLASTIC CONSTRUCTION) SPECIFICATIONS

Vessel Dimensions: ....44¼" x 44¼" x 89⅜"

Inlet & Discharge Connections:................6" Φ PS 15-69 Duct Flanges

Carbon Volume: ....60 cu. ft. (1800 lbs)

System Shipping Weight: ....New - 2200 lbs
Spent - 4000 lbs

Temperature Rating:...............................150°F max

Static Pressure Rating above carbon level:.................................20" W.C. max

Vacuum Pressure Rating above carbon level: ....2" W.C. max

All units shipped F.O.B., Pittsburgh, Pennsylvania

MATERIALS OF CONSTRUCTION

Vessel: ....Polyethylene

Frame: ....Carbon Steel coated with Sherwin Williams Tile Clad II

Inlet Flanges, Elbow, Septum: ....PVC

Discharge Flange: ....Polyethylene

Fasteners & Bottom Valve Support Plate: ...Steel, Plated

Sample Fittings & Sample Canister: ....PVC

VAPOR PAC (STAINLESS STEEL) SPECIFICATIONS

Vessel Dimensions, Diameter: ....5'
Height: ....7' 3"

Inlet & Discharge Connections: ....8" Φ PS 15-69 Duct Flanges

Carbon Volume: ....60 cu. ft. approx. (1800 lbs)

System Shipping Weight: ....New - 2840 lbs
Spent - 4640 lbs

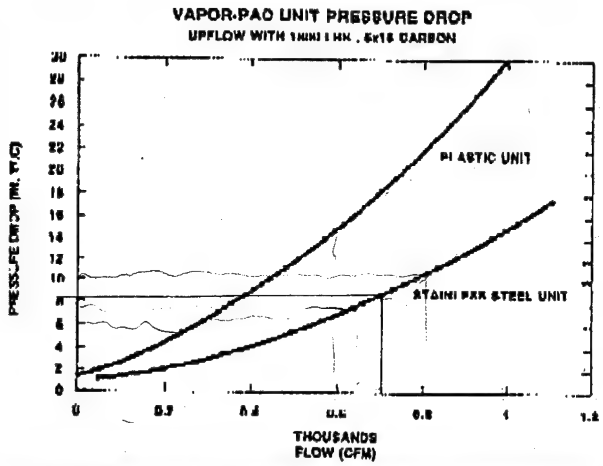
Static Pressure Rating above carbon level: ....15 psig

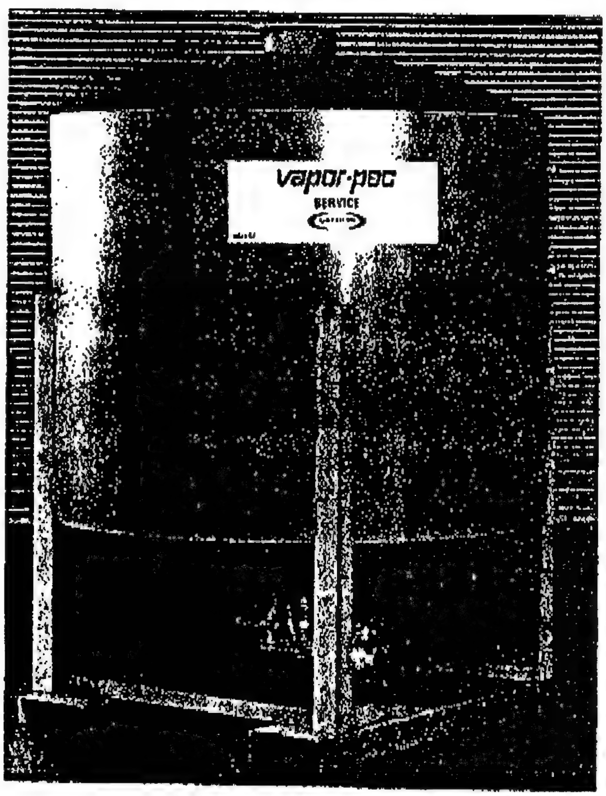
Vacuum Pressure Rating above carbon level: ....Full

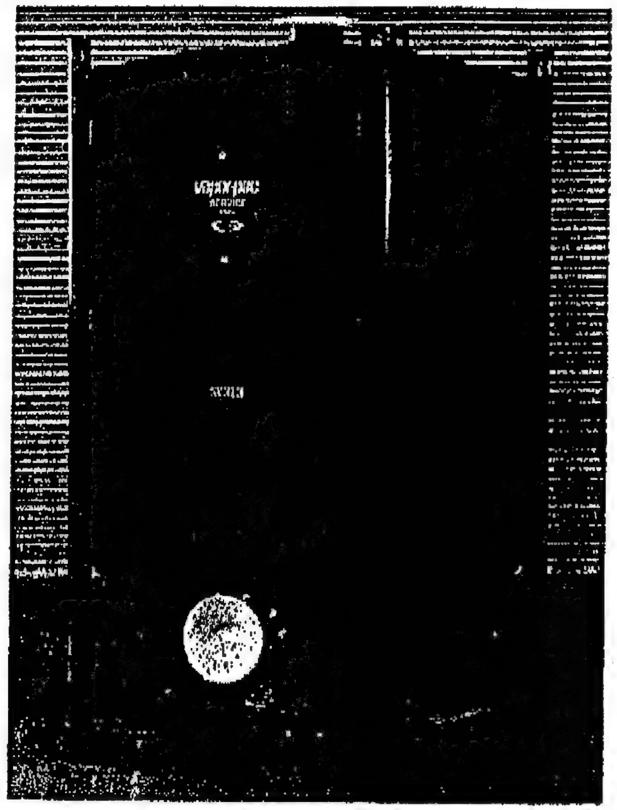
All units shipped F.O.B., Pittsburgh, Pennsylvania

MATERIALS OF CONSTRUCTION

Vessel: ....316L Stainless Steel
Skid and Support Frame: ....304 Stainless Steel
Inlet Flanges, Elbow, Septum: ....316L Stainless Steel
Discharge Flange: ....316L Stainless Steel
Fasteners & Bottom Valve
  Support Plate:...................................Steel, Plated
Sample Fittings &
  Sample Canister: ....316L Stainless Steel







CAUTION

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing activated carbon, appropriate sampling and work procedures should be followed, including all applicable federal and state requirements.

For information regarding human and environmental exposure, call Calgon Carbon's Regulatory and Trade Affairs personnel at (412) 787-6700.

INSTALLATION INSTRUCTIONS

See Bulletin #27-199 for details on how to install a Vapor-Pac.

SAFETY CONSIDERATIONS

See Safety Bulletin #27-198 for important safety considerations.

OPTIONAL EQUIPMENT

Inlet and outlet flange connectors for hose connections.

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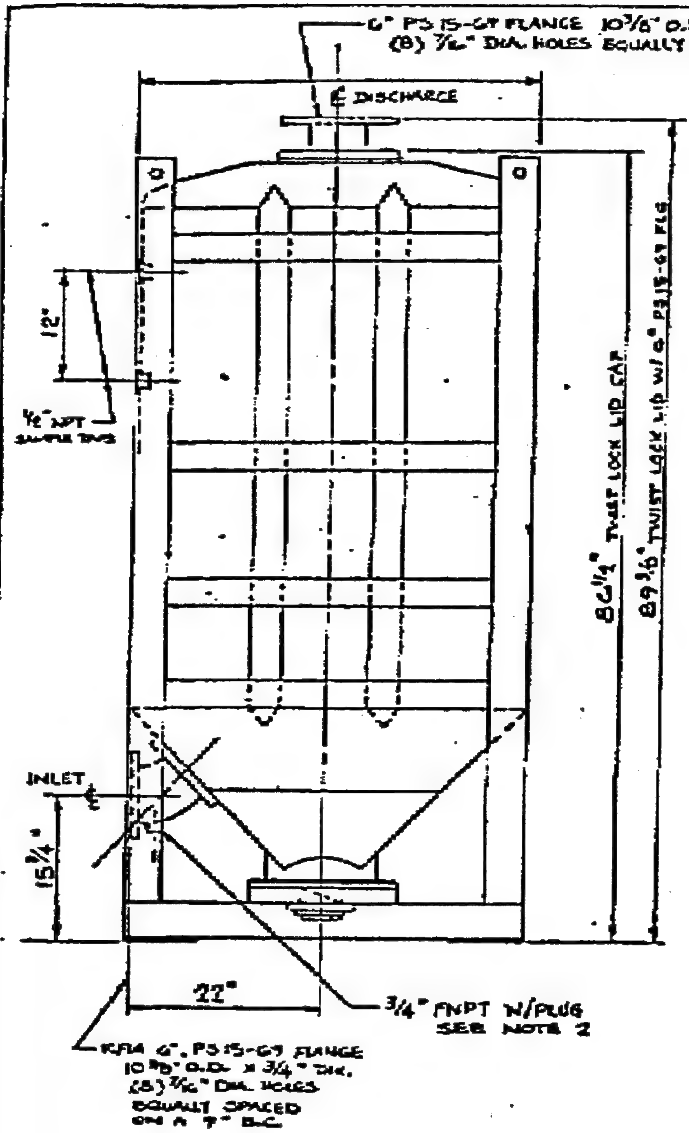
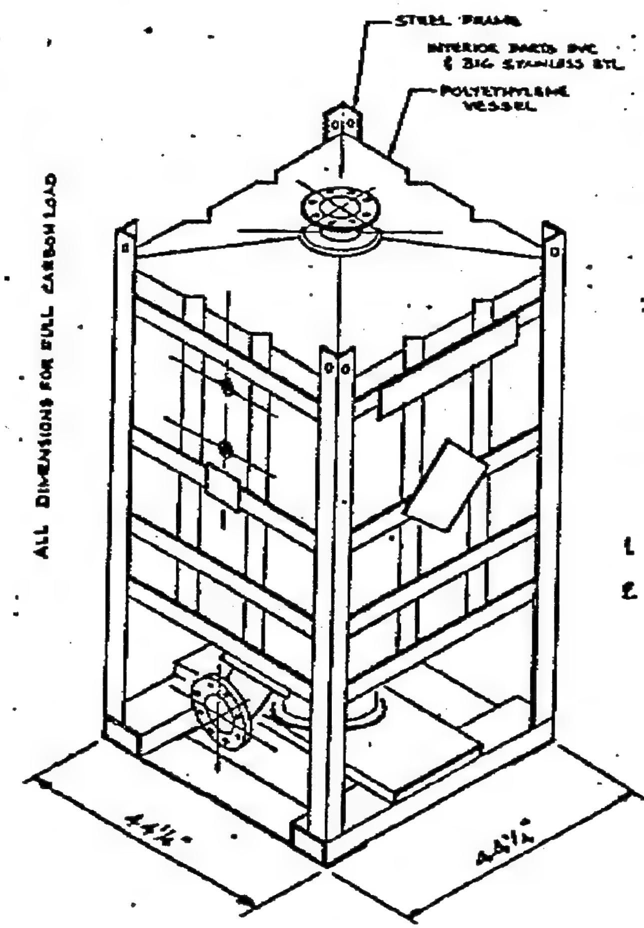
For additional information, contact Calgon Carbon Corporation, Box 717, Pittsburgh, PA 15230-0717, Phone (412) 787-6700



ALL DIMENSIONS FOR FULL CARBON LOAD



Empty weight: 4 400 lbs

Capacity: 70 cu ft

carbon charge ______ 3,000 lbs

Cross-section area: 13.4 sq ft

Estimated carbon depth above septa: 50"

Pressure drop: upflow

400 CFM ____ 10" W.C.
500 CFM ____ 13" W.C.
600 CFM ____ 16" W.C.
700 CFM ____ 17" W.C.

Temperature rating (liner): 150°F max.

STATIC VACUUM RATING ABOVE CARBON LEVEL 1" W.G.

STATIC PRESSURE RATING ABOVE CARBON LEVEL 10" W.G.

NOTE:

1. DO NOT SUPPORT CONNECTING DUCTWORK OR EQUIPMENT FROM INLET/OUTLET FLANGES.
2. OPTIONAL SAMPLE CANISTER AVAILABLE FOR CONNECTION TO INLET ELBOW.

1	AS BUILT REVISION	JS	
NO.	REVISION	BY	DATE

PLANT TO CUSTOMER GENERAL

TITLE: VAPOR-PAC SERVICE UNIT

DWG. NO. 90-87-1646 REV. 1

PROJECT	
SCALE	NONE
DRAWN	AWF
DATE	8-11-87
CHK'D	
APPRVD	K.D.

CALGON

CALGON CARBON CORPORATION P.O. BOX 717 PITTSBURGH, PA 15230-0717

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CALGON CARBON CORPORATION

VAPOR-PAC 10 SERVICE FOR VOC CONTROL

The increasing emphasis on cleaner air presents industry with new challenges to control and reduce toxic volatile organic compounds (VOCs) at air emission sources.

To help plant managers comply with current and future VOC regulations, Calgon Carbon has available the Vapor-Pac 10 Service which utilizes adsorption on granular activated carbon to remove VOCs from air emissions and other vapors. The service also minimizes capital expenditures and eliminates on-site spent carbon transfer and regeneration.

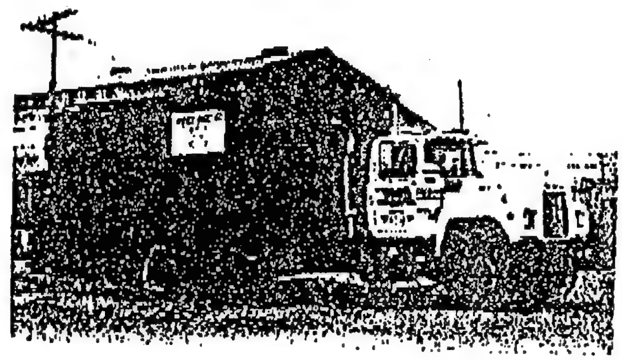
The Vapor-Pac 10 Service uses a transportable adsorber which contains approximately 12,500 pounds of granular activated carbon and can treat air flows up to 10,000 scfm. When the activated carbon has fully utilized its capacity to remove the VOCs, the onstream adsorber is replaced with one containing fresh carbon. The use of the Vapor-Pac 10 Service minimizes capital expenditure, as the only site facilities normally required would be ductwork and a fan. Calgon Carbon provides the entire service for the adsorption process which includes spent carbon removal, transport and reactivation. The use of the service is dependent upon the spent carbon material being acceptable by Calgon Carbon's reactivation facility. The Vapor-Pac 10 adsorbers are owned by Calgon Carbon, who will maintain the units in operable condition.

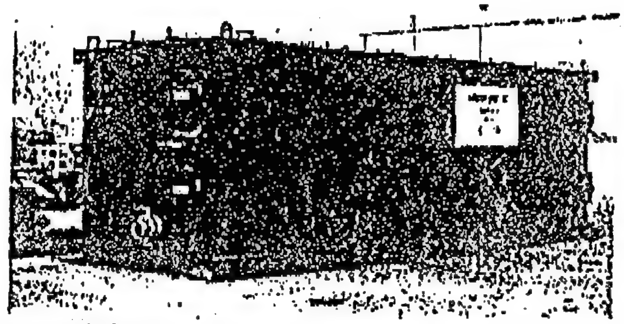
Vapor-Pac 10 units are ideally suited to remove low concentrations of VOCs from industrial plant emissions and soil remediation vents, as well as VOCs from air stripper off-gases.

In order to handle a wide range of flows and VOC concentrations efficiently, the Vapor-Pac 10 unit as an option can contain two separate adsorber beds. Each bed would contain approximately 6,500 pounds of activated carbon. Depending on the flow and VOC concentration, the beds can be used one at a time or both beds can be operated in parallel and used simultaneously. A three-foot deep carbon bed in each section is provided for effective removal of VOCs, even during periods of peak concentrations.

To determine carbon life in the Vapor-Pac 10, Calgon Carbon recommends monitoring the performance via the sample ports which are provided. Frequency of unit exchange will depend on the types and concentrations of VOCs being treated. Exchange should be scheduled before carbon breakthrough occurs. If the beds are used sequentially, the timing of the breakthrough from the second bed can be estimated by comparing it with the breakthrough time for the first bed (assuming that they operate under similar conditions).

When an exchange is required, Calgon Carbon delivers a replacement unit from Pittsburgh, Pa. Upon delivery of the replacement, the unit containing the spent carbon is





removed from the process and the replacement unit is placed on-line to continue treatment. The unit removed from the process is returned to our reactivation facility, where it is emptied, inspected, refilled, and stored in preparation for the next exchange.

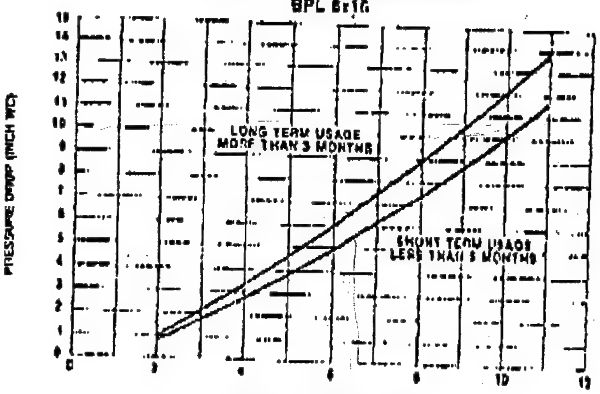
Your Calgon Carbon Technical Sales Representative can help in the evaluation of the suitability of the Vapor-Pac 10 Service to satisfy your air treatment requirements. If required, evaluation studies to determine applicability and economics can be arranged. Calgon Carbon offers other adsorption equipment, including permanent installations, smaller service equipment, and unique systems incorporating on-site regeneration to meet particular needs.

BENEFITS

- Removes toxic VOCs
- Eliminates on-site carbon handling
- Minimizes spent carbon disposal concerns
- No major capital investment required
- Supply of virgin activated carbon
- No on-site equipment required for loading or offloading

SPECIFICATIONS

Vessel Dimensions..................22'-4" x 8'-0" x 8'-4"
Inlet Duct Connections..........20" ID (two on each end)
Outlet Duct Connections..............20" ID (four on top)
Carbon Volume..425 ft³
Carbon Weight (Approximate)...........12,500 lbs (Coal)
12,000 lbs (Coconut)
Shipping Weight.................Fresh -- 27,500 lbs (max)
Spent -- 35,000 lbs (max)
Temperature Rating...............................150° F max
Static Pressure Rating...............................0.5 psig
Vacuum Pressure Rating...............................None



MATERIALS OF CONSTRUCTION

Vessel.....................................Epoxy Carbon Steel
Internals..................................Epoxy Carbon Steel
Internal Screen................................Polypropylene
Carbon Acceptance Canister
and Associated Fittings.....................................PVC

CAUTION

Wet activated carbon preferentially removes oxygen from the air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers enter a vessel containing carbon, appropriate sampling and work procedures for potentially low oxygen spaces should be followed, including all applicable federal and state requirements.

For additional information regarding human and environmental exposure, please call Calgon Carbon's Regulatory & Trade Affairs department at (412) 787-6700.

For additional information, contact Calgon Carbon Corporation, Box 717, Pittsburgh, PA 15230-0717 Phone (412) 787-6700

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Temperature Rating:	150 deg. F
Static Pressure Rating:	0.5 psig
Vacuum Pressure Rating:	None
Materials of Construction:	
Vessel -	Carbon Steel
Internals -	Carbon Steel
Internal Screen -	Polypropylene
Internal Coating -	Coal Tar Epoxy
External Coating -	Coal Tar Epoxy
Carbon Acceptance Canister -	PVC
Air Flow Rate:	500 - 10,000 cfm
Internal X-Sectional Area:	30 sq. ft.

Installation Instructions

Initial Set-Up:

Off-load vessel on level ground or concrete pad. Calgon Carbon's delivery truck is the only equipment needed for this step. For off-loading the vessel, the maximum overhead clearance needed is 20'; the maximum overall length needed is 80'.

Carbon Bed Inspection:

Open the carbon doors (square doors) on top of the vessel and inspect the carbon bed for settling that occurred during shipment. Some activated carbon may have to be added to "top-off" the bed so that short circuiting of the inlet stream does not occur. Extra carbon can be found in the storage compartment on the rear of the vessel.

Duct Connections:

Install 20" ID flexible inlet and outlet ductwork to the inlet and outlet manholes of the Vapor-Pac 10 with banding. All manholes are marked "INLET" or "OUTLET" on the outside of the manhole cover for easy identification.

Operating Instructions

Start-up:

Once the Vapor-Pac 10 is in place with ductwork connected, startup is accomplished simply by starting the fan which supplies the contaminated air. The pressure across the unit should be checked to compare with design expectations.

If carbon acceptance has not yet been approved by Calgon Carbon, it will be necessary to obtain a sample of the spent carbon. The sample can be obtained using the carbon acceptance canister located on either end of the Vapor-Pac 10 unit. Simply open the 3/4" PVC valve upstream of the canister which is filled with approximately one quart granular activated carbon. When the carbon in the canister is spent, send the sample back to our laboratories in Pittsburgh, PA for testing.

October 22, 1990 Rev. 1

VAPOR-PAC 10 GENERAL INFORMATION

General Description

Calgon Carbon's Vapor-Pac 10 is to be used for the removal of Volatile Organic Compounds (VOC's) from miscellaneous vapor emissions using granular activated carbon adsorption. The unit is designed and fabricated to contain 12,000 to 14,000 pounds of vapor phase granular virgin or reactivated carbon for treatment of vapor streams up to 10,000 cfm. It is modular and serves as both adsorber and shipping container. No crane or additional equipment is required to off-load or load the adsorber.

The unit containing virgin or reactivated carbon is provided as a service of Calgon Carbon to remove VOC's from miscellaneous air/gas streams such as those from industrial processes, air-stripper off gases, and soil remediation processes. Thus, there is no need for large capital expenditure for equipment procurement, nor is there any on-going maintenance expenditure since the equipment is owned by Calgon Carbon Corporation.

The frequency of exchange of the units will depend on the type and amount of VOC's removed, and it is recommended that the effluent from the unit be monitored for breakthrough. A unit exchange should be scheduled before breakthrough occurs. When an exchange is required, simply call Calgon Carbon and we will ship the unit stored at our Pittsburgh, PA facility. When the fresh unit is delivered, the same truck will pick up the spent unit and return it to our Pittsburgh, PA reactivation facility -- provided the spent carbon meets our acceptance criteria -- where the spent carbon will be unloaded and reactivated. The returned unit will then be inspected, repaired if necessary, filled with virgin or reactivated carbon, and retained at our site, ready for the next exchange.

Specifications

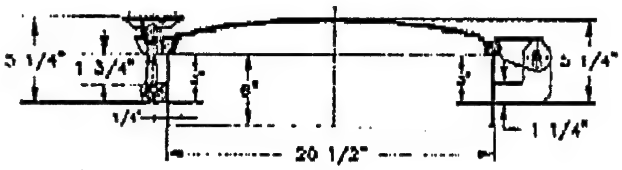
Vessel Dimensions:	22'-4"L x 8'-0"W x 8'-4"H
Bed Width:	3'-0"
Inlet Duct Connections:	20" ID (two each end)
Outlet Duct Connections:	20" ID (four on top)
Carbon Volume:	425 cu. ft.
Carbon Weight (approximate):	14,000 # 8x30 React C 12,500 # 6x16 BPL 12,000 # 6x16 GRC-11 & GRC-22
Shipping Weight:	Empty - 13,500 # Filled w/carbon - 27,500 (max) Spent - 32,500 # (max) Spent & washed - 35,000 # (max)

Operation:

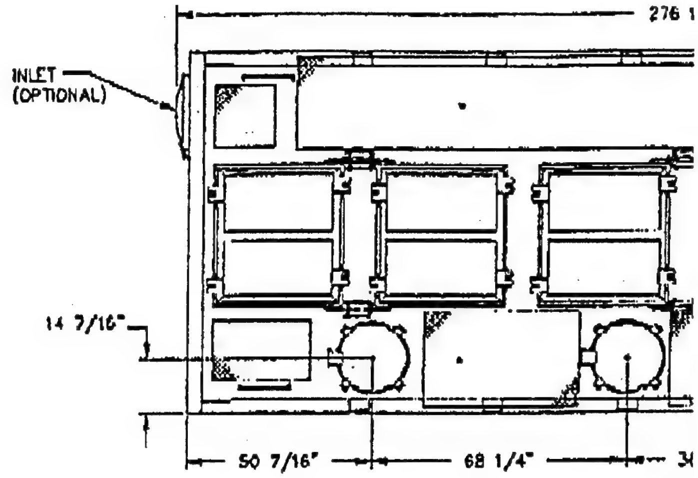
The pressure across the carbon bed should be checked periodically. A sudden increase in pressure drop may indicate the entrapment of some solid materials in the carbon bed. Severe solid build-up may require the carbon to be replaced.

Monitoring:

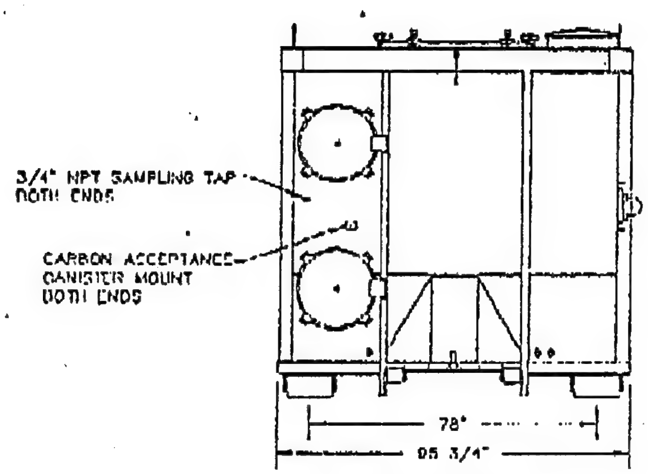
Air monitoring on the Vapor-Pac 10 can be achieved using any of the four sampling taps located on the sides of the unit. Two sampling ports are located on the inlet plenum and two are located on the outlet plenum. These ports are also convenient points at which pressure drop measurements can be taken. Close monitoring should be a routine practice so that lead time is available for unit replacement.



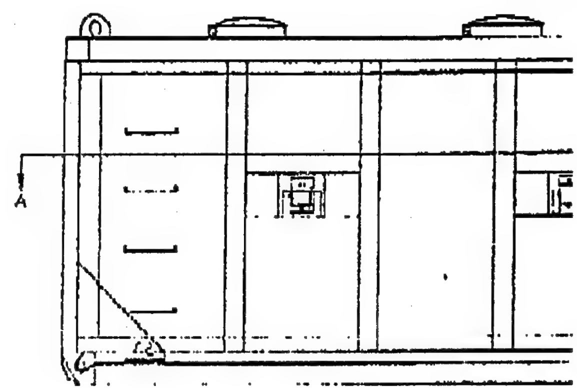
MANHOLE DETAIL



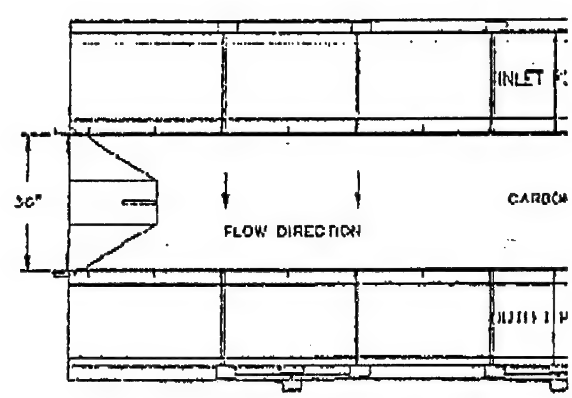
PLA



END VIEW



ELEVA

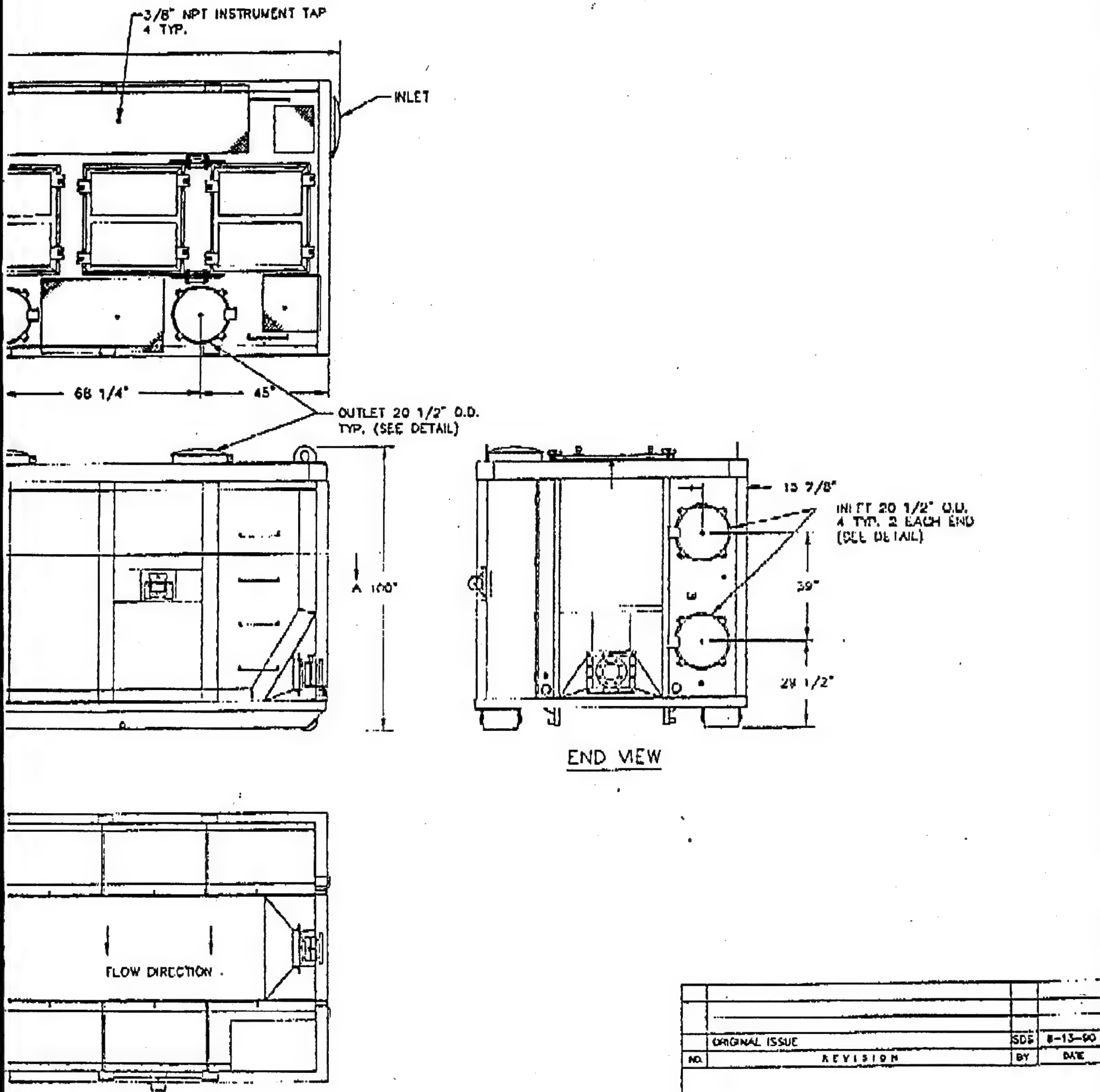


SECTION
PLA

MATERIALS OF NSTRUCTION	VESSEL	CARBON STEEL
	INTERNALS	CARBON STEEL
	INTERNAL SCREENS	POLYPROPYLENE
	CARBON ACCEPT. CANISTER	PVC
	INTERNAL COATING	COAL TAR EPOXY

PECIFICATIONS

BON VOLUME AND WEIGHT	417 CUBIC FEET (12,500 LBS.)
	VIRGIN CARBON 25,000#
	SPENT CARBON 32,500#
MPERATURE RATING	150 DEG. F MAX
ATIC PRESSURE RATING	0.5 PSIG
CUUM PRESSURE RATING	NONE
XIMUM FLOW	10,000 CFM



NO.	REVISION	BY	DATE
	ORIGINAL ISSUE	SDS	8-13-90

PLOTTED 8-1-90

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P. O. BOX 717 PITTSBURGH, PA 15230-0717

PLANT: CUSTOMER GENERAL

TITLE: GENERAL ARRANGEMENT VAPOR PAC 10

DRAWN	CHECKED	APPROVED	SCALE
TLH	S. SPOTTS	J. MICKLER	N.T.S.
PROJECT: APP0052	DRAWING NO. 90-30-0188		REV.

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TYPE BPL GRANULAR CARBON

Type BPL Activated Carbon is designed for use in vapor phase applications, and is available in several mesh sizes to suit specific design requirements. It is made from selected grades of bituminous coal combined with suitable binders. These binders impart the superior hardness that is necessary for the long life expected in such applications. Produced under rigidly controlled conditions by high temperature steam activation, BPL Carbon provides high surface area, fine pore structure, high density, high volume activity and ease of reactivation. Because of its unique raw material base, this adsorbent also offers unusual economy in use.

Applications of Type BPL cover the whole vapor adsorption field, typical of which is the familiar solvent recovery system. BPL is used for the adsorption and recovery of alcohols, chlorinated hydrocarbons, esters, ketones, ethers, hydrocarbons, and aromatics.

Type BPL is used almost universally as the catalyst support in the acetylene process for the production of vinyl chloride and vinyl acetate monomers. Here, high conversion rates and exceedingly long life mark its performance. It is also used as a direct catalyst in the production of phosgene and other similar reactions.

In fixed-bed adsorbers, Type BPL is used for the separation of hydrocarbon gas streams, such as the recovery of C_3 and C_4 cuts from natural gas. Similarly, organic sulfur, COS, and higher hydrocarbons are stripped from methane and hydrogen for catalytic conversion processes.

Other applications include purification of carbon dioxide for beverage use and dry ice; removal of chlorine, chlorinated organics and aromatics from anhydrous hydrogen chloride; purification of acetylene, hydrogen, compressed air, etc.

Air sterilization for aerobic fermentation can be accomplished with deep beds of BPL. It is widely used in air conditioning systems and for abatement of air pollution where plant air exhausts are odorous or harmful.

Because of their unusual adsorptive powers and high volume activity, vapor phase carbons are widely used for military gas masks and industrial respirators.

PHYSICAL PROPERTIES

Total Surface Area (N_2, BET Method), m^2/g	1050-1150
Apparent Density (Bulk Density, dense packing), Typical, g/cc	0.48
lb/ft^3	30.0
Particle Density (Hg Displacement), g/cc	0.85
Real Density (He Displacement), g/cc	2.1
Pore Volume (Within Particle), cc/g	0.7
Voids in Dense Packed Column, %	43
Specific Heat at 100°C	0.25

SPECIFICATIONS

Iodine Number, Minimum	1050
Carbon Tetrachloride Adsorption, Minimum, Weight %	60
Ash, Maximum, %	8
Moisture (as packed), Maximum, %	2
Hardness Number, Minimum	90-93
Apparent Density (Bulk Density, dense packing), g/cc, Minimum	0.47

COMMERCIAL INFORMATION

Shipping Points: Pittsburgh, Pennsylvania; Catlettsburg, Kentucky.

Mesh Sizes: 4 x 10, 6 x 16, and 12 x 30 U. S. Sieve Series.

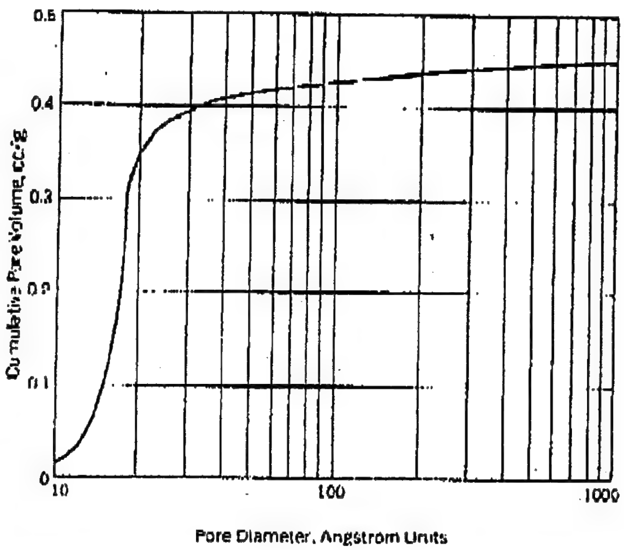
Packaging: Packed in 55 gallon Leverpak drums, 200 lb. net, 217 lb. gross weight.

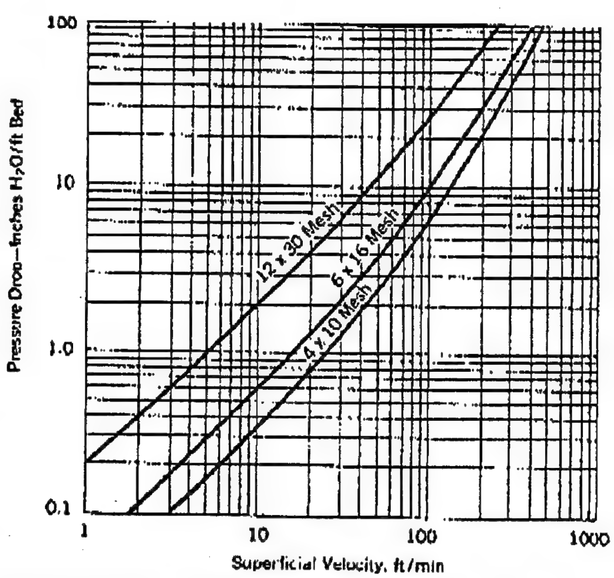
PORE STRUCTURE

The micropore structure of Type BPL carbon is illustrated at the right where the cumulative pore volume is plotted against pore diameter. The pore size distribution data are obtained from the water desorption isotherm.[1] Examination of the curve indicates that a large portion of this micropore volume is in pores of 15 to 20 Angstrom units in diameter. These small pores are accessible to all common gases and vapors, and therefore provide the maximum surface area for adsorption. The structure of the pores provides good retention of the adsorbed molecules while at the same time allowing high working capacities in systems providing for reactivation of the carbon.

In addition to the micropore structure, Type BPL is permeated by a system of macropores (pores larger than 1000 Angstroms in diameter) which serve as avenues for the rapid diffusion of gases to and from the micropore surfaces. This enhances both adsorption and reactivation characteristics.

[1]Juhola and Wiig J. Am. Chem. Soc. 71, 2069 (1949)





PRESSURE DROP CHARACTERISTICS

Pressure drop, in inches of water per foot of bed depth, measured in air at 70° F. and 1 ATM, can be read above for standard mesh sizes of BPL Carbon. These data were obtained with a dense packing arrangement (30 lbs./ft.^{3}) and should be used for design purposes.

Loose packed beds (26 lbs./ft.^{3}) give a pressure drop approximately one-third of a dense bed. In making adsorption calculations a bulk density (of 30 lbs./ft.^{3}) should be used.

SCREEN SIZE SPECIFICATIONS, U.S. SIEVE SERIES TYPE BPL STANDARD MESH SIZES

Sieve No.	% Retained
4 x 10	
+4	0-5
4 x 6	30-50
6 x 8	30-50
8 x 10	5-20
-10	0-3
6 x 16	
+6	0-5
6 x 8	30-50
8 x 12	30-50
12 x 16	10-25
-16	0-5
12 x 30	
+12	0-5
12 x 16	10-30
16 x 20	40-65
20 x 30	10-35
-30	0-5

For additional information, contact the Calgon Carbon Corporation, Box 717, Pittsburgh, PA 15230-0717 Phone: (412) 787-6700

CALGON CORPORATION

SUBSIDIARY OF MERCK & CO., INC.

CALGON

CALGON CARBON CORPORATION

2121 S. El Camino Real San Mateo, CA 94403-1801

Attention: Mr. Joe Scott

Date: May 1, 1992

Company: Woodward Clyde Consultants

Phone: 303/740-3917

From: *Martha C. Alvarez*

Fax #: 303/694-3946

Subject 48" High Flow Ventsorb

No. Of Pages: 1 of 3

Comments:

Dear Mr. Scott:

Attached please find the brochure for our 48" High Flow Ventsorb that Mr. Steven C. Wood had promised you. The drawing for a 12' DiAmeter Dual Bed will follow under separate cover.

Thanks in advance for your patience and cooperation.

Regards,

Martha Alvarez

Martha C. Alvarez

Regional Office Manager

PLEASE CALL IF YOU DO NOT RECEIVE THE TOTAL NUMBER OF PAGES

Phone # (415) 572-9111 Fax # (415)574-4466

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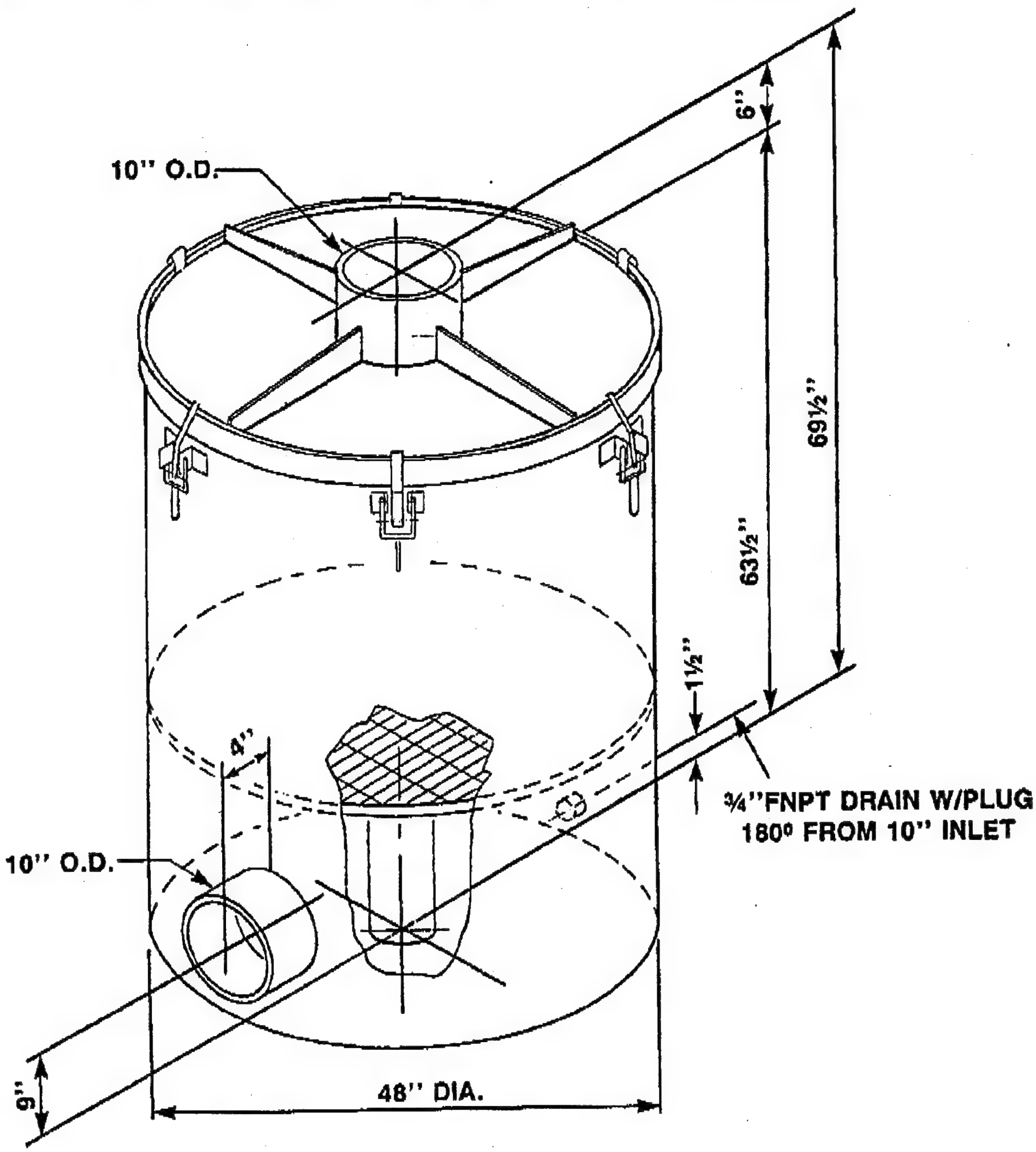
48" HIGH FLOW VENTSORB



CALGON CARBON ID:4155744466 MAY 01 '92 14:32 No.016 P.02

SPECIFICATIONS

Canister: Polypropylene
Grating: FRP
Fasteners: 316 SS
Max Temperature: 150°
Max Pressure: 15 in. W.G.
Max Vacuum: 10" in. W.G.
Empty Weight: 140 Lbs.
Filled Weight: 1140 Lbs./BPL
Filled Weight: 1265 Lbs./IVP 4 x 6

Type GAC	Max. Lbs.	Max. Flow SCFM	ΔP @ Max. Flow In. W.G.
IVP 4 x 6	1125	1200	9½
BPL 4 x 10	1000	1100	15
BPL 4 x 6	1000	1200	10½

NOTE:

1. Optional flanged inlet/outlet are PS 15-69 std., $14^3/_8$ O.D. x $^3/_8$" thick. (12) $^7/_{16}$" diameter holes, equally spaced, 13" B.C.
2. Pressure drop values based on average packed bed conditions. Actual conditions may be different resulting in higher or lower pressure drop.

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27-161

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CALGON CARBON CORPORATION

2121 S. El Camino Real San Mateo, CA 94403-1801

Attention: JOE SCOTT

Date: 5-5-92

Company: WOODWARD CLYDE

Phone: (303) 740-3917

From: STEVE WOOD

Fax #: (303) 694-3946

Subject: DUAL BED VAPOR PHASE ADSORBER

No. Of Pages: 3

Comments:

JOE -

IT TOOK ME AWHILE TO FIND A DRAWING, BUT HERE IT IS. GIVE ME CALL IF YOU NEED ADDITIONAL INFORMATION

REGARDS.

Steve Wood

PLEASE CALL IF YOU DO NOT RECEIVE THE TOTAL NUMBER OF PAGES

Phone # (415) 572-9111

Fax # (415)574-4466

EL SELECTION AND
SSEL APPURTENANCES
D BY CUSTOMERS DE-

¢ VESSEL ¢ FAN

LEGEND

ITEM Nº	DESCRIPTION
1	DOME MANWAY
2	GASKETED SEAT DAMPER
3	OUTLET NOZZLES
4	STN. STL. GROUNDING RODS
5	LIFTING LUGS
6	CARBON REGENERATION OVER-FLOW ASSY.
7	MANOMETER W/TAPS & TUBING
8	HOLD-DOWN BRACKETS
9	INLET NOZZLE
10	CARBON SAMPLE PROBES
11	TRANSITION
12	FLEX CONNECTION
13	DRAIN

12,000 lbs GAC Recommend
BPL 4x10, or BPL 6x16
6" H_2O ΔP @ 13,000 cfm
Max vacuum 5-6" H_2O

GENERAL NOTES:

1. ALL VESSEL, FAN AND DUCTWORK MATERIAL TO BE FIBERGLASS REINFORCED PLASTIC.
2. FABRICATION WILL BE AS PER A.S.T.M. SPECIFICATION D-3299 AND PS 15-69.
3. LIFTING LUGS AND HOLD-DOWN BRACKETS WILL BE CADMIUM PLATED STEEL.
4. GASKETING MATERIAL AND FLEX-CONNECTION WILL BE NEOPRENE.
5. VESSEL PIPING APPURTENANCES WILL BE SCHEDULE 80 C.P.V.C.
6. BOLTING HARDWARE WILL BE STAINLESS STEEL

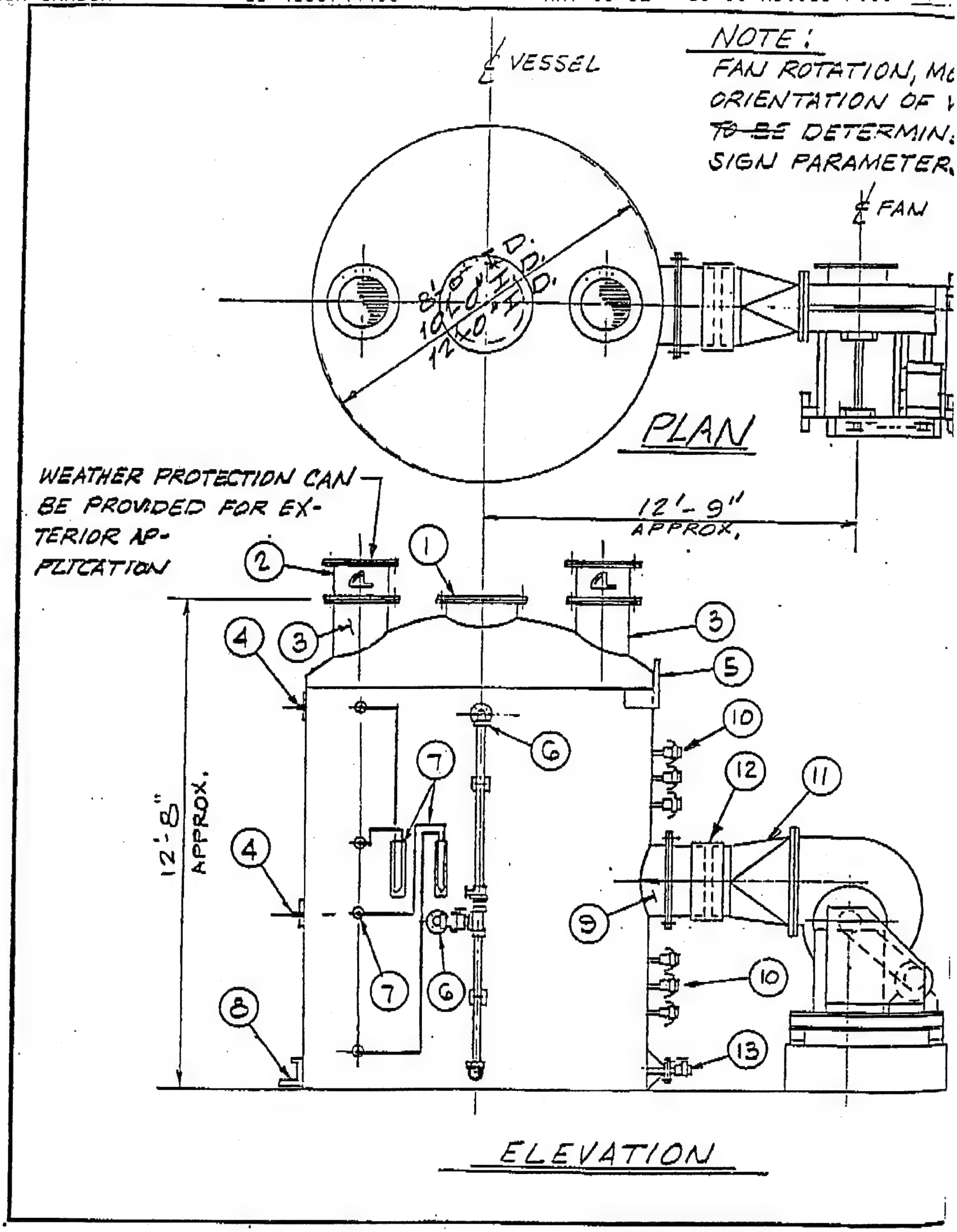
PROJECT	
SCALE	NONE
DRAWN	BF
DATE	1-20-86
CHK'D.	MUS
APPRV'D.	

CALGON
CALGON CARBON CORPORATION
P.O. BOX 717 PITTSBURGH, PA 15230-0717

PLANT CUSTOMER GENERAL

TITLE ODOR CONTROL SYSTEM 8', 10', & 12' DUAL BED ADSORBER

DWG. NO.	REV.
90-30-0267	0


NOTE:
FAN ROTATION, M
ORIENTATION OF
~~TO BE~~ DETERMIN
SIGN PARAMETER
℄ VESSEL
℄ FAN
8'-0" I.D.
10'-0" I.D.
12'-0" I.D.
PLAN
WEATHER PROTECTION CAN BE PROVIDED FOR EXTERIOR APPLICATION
12'-9" APPROX.
12'-8" APPROX.
1
2
3
4
5
6
7
8
9
10
11
12
13
ELEVATION

APPENDIX B
CIVIL/STRUCTURAL CALCULATIONS

Subject: Volume Calcs for liners
Project No. 89C114MM
Task No. 5
By G. Greg Lord
Checked By [illegible]
File No.
Date 5-8-92
Date [illegible] 92
Sheet 1 of 2

Problem: Calculate Quantities (in tons) of material, by type, to go to offsite landfill.

Given: Tank 102 78.5' Ø x 40' High

100 mil HDPE liner throughout

200 mil Geonet drainage net

1) Assume continuous around walls 12' wide strips 10' OC

Solution: Total (worst case) 5 Tons

Liner - bottom

$$\pi \frac{(78.5)^2}{4} = 4840 \text{ sf}$$

Liner - sides

$$\pi (78.5)(40) = 9865 \text{ sf}$$

14,705 sf

$0.498 \#/\text{sf} \cdot 14{,}705 \text{ sf} = 7316 \#$

$= 3.66$ tons

Drainage net 1)

$\pi (78.5)/10 \cong 25$ sheets

$25 \text{ sheets} \times \frac{12' \times 40'}{\text{Sheet}} = 12{,}000 \text{ sf}$

$12{,}000 \text{ sf} \times 0.22 \#/\text{sf} \div 2000 \#/\text{ton} = 1.32$ Tons

Subject: Volume Calcs for Decontamination
Project No. 89C114MM
Task No. 5
By: GGL
Checked By: JPS
File No.
Date: 5-8-92
Date: 6/1/92
Sheet 2 of 2

Problem: Calculate the volume of water generated during decontamination of Liners, Geonets, Alumadome roof and tank walls.

Given: Tank 102 78.5' Ø × 40' Tall

100 mil HDPE Liner Throughout

200 mil Geonet continuous around sides

Alumadome roof

cleaning will require approximately 4 gals/sf

Solution:

Liner - Walls + bottom - both sides

2 × (14705sf) = 29410 sf

Geonet - walls - 1 side 12000 sf

Alumadome roof

4840 sf × 1.5 = 7260 sf

Tank - Sides + bottom 14705 sf

63 375 sf

63 375 sf × 4 gals/sf + 25000 gals* = 278,500 gals

*assume 25,000 gal misc appurtenances

Woodward-Clyde Consultants

APPENDIX C
MECHANICAL DESIGN CALCULATIONS

MECHANICAL DESIGN CALCULATIONS FOR LIQUID HEATING AND RECIRCULATION SYSTEM

SUBJECT: Design Analysis
DESIGN ITEM: Fluid distribution in Tank
PROJECT NO: 89C 114 MM
TASK NO: 5.3
BY: W. W. Irving CHK.'D BY: Joseph Scott FILE NO. .1
DATE: 5/28/92 DATE: 6/3/92 SHEET: 1 OF

Design Criteria:
1. The fluid in the tank need not be energetically agitated to stir up solids.
2. Existing suction outlets from tank will govern flow quantity.
3. Dilution fluid may be either fresh water or fluid from Pond A.
4. Heated fluid returned to tank to be evenly distributed across tank.
5. Two foot maximum depth of free fluid in tank.

Design Conditions for Design Basis:
1. Do not cut new discharge openings into tank thru wall & liner.
2. Cutting new openings thru the manholes is OK. No liner on inside.
3. There are 3- 6" connections low in tank for withdrawing fluid.

Type of System:
1. Install a distribution header across the diameter of the tank.
2. Provide orifice holes at uniform intervals across distribution header, with one hole on each side, 15^{o} below the horizontal.
3. Select header with neutral bouyancy so top of header floats at surface.
4. Header to allow for thermal expansion.
5. Corrosion of any common inexpensive steel material is severe.

Equipment Selection:
1. An HDPE pipe is selected because:
   It has neutral bouyancy
   It will not corrode
   It is relatively inexpensive.
   Orifices should be easily drilled.

2. Concerns about using this material:
   The fluid temperature inside the header will be close to material temperature limit.
   As you approach material temperature limit, material softens.
   If there are heavy solids concentrations in fluid, softned header material may erode. We are not sure how much to expect.

Connection to Existing Systems:
1. Two of the existing 6" connections connect to the SQI but will not be used during this operation.
2. A third 6" connection is not presently connected to anything.
3. Connection to these lines will allow this installation without new holes.
4. Use two distribution headers each taking half the total flow, and each extending half way across the tank, to return heated brine to the tank.

SUBJECT: Design Analysis
DESIGN #Fluid distribution in Tank PROJECT N89C 114 MM

				TASK NO:	5.3
BY:	W. W. Irv	CHK.'D BY:	JTS	FILE NO.	1
DATE:	5/28/92	DATE:	6/3/92	SHEET:	2 OF

==

Calculations:

Flow Limits:
There are two 6" connections 8" from the bottom of the tank. Another 6" connection is 4'-0" from the bottom of the tank. We should not count on this upper connection as a suction point. We are therefore limited to the flow through 2- 6" connections.

Based on several sources the entrance velocity from the tank into the pipe system should be limited to ≈ 4.5 FPS

6" Pipe Area- Sq.Ft.=	0.1963 ⌀
Factors: Sp. Gr. = 1.2	
Fluid Density = Water Density x Sp.Gr.	74.9 #/Cu.Ft.
Wgt/ Gal.= Water Wgt/ Gal x Sp. Gr.=	10.0 #/Gal.

Area x Vel.= Vol.Flow= 0.1963 x 4.5 = 0.88 CFS = 397 GPM
Mass Flow 397 x 10.0 = 3970 #/Min

Size the system for 2- 6" heating circuits at 400 GPM each. This is about as much as we can expect to get through each 6" tank connection. We don't want to circulate less because of our fluid temperature limit and desire to heat tank up in about 24 hours. Header velocity therefore will be 4.5 FPS. It is known from experience that if the orifice velocity is 3 times the header velocity, the flow thru the orifices will equalize. Therefore orifice velocity should be about 14 FPS, and the total area should be about
0.1963 ÷ 3 = 0.0654 Sq.Ft.

The following design calculations are for a single distribution header. The second header will be identical.

Header Length	39.25 Ft.
Orifice Spacing- Designer's choice	3 Ft
Orifices/Space	2
# of Orifices	26
Area/Hole=0.00250⌀ = 0.677" Dia. ≈ 0.625" Dia =	0.0021 Sq.Ft.
Flow/Hole 15.3 GPM =	0.034 CFS

Formula for Orifice Flow (RE: Kents where

$Q = C \times a \times (2 \times g \times H)^{0.5}$	Q= 0.034 CFS
3.3 = H^0.5	C= 0.61
H= 10.6 Ft.	a= 0.00213 Sq. Ft.
Hdr.Entrance Press. ≈ 11 Ft	g= 32.2 Ft./Sec/Sec

SUBJECT: Design Analysis
DESIGN ITEM: Fluid Distribution in Tank

BY: W. W.	CHK.'D BY: JPS	PROJECT NO:	89C 114 MM
DATE: 5/28/	DATE: 6/3/92	TASK NO:	5.3
		FILE NO.	1
		SHEET:	3

==

Check to determine flow variation from first to last orifice.

Given:
- 6" Header diameter
- 26 - 5/8" Diameter orifices
- 39.25 Ft. Header length
- 2 orifices every 3 feet
- 400 GPM = Flow entering header.
- 10.6 Ft. initial pressure.

Applicable formulas:
Pipe loss 0.2083*(100/C)^1.85*((q)^1.85)/d^4.8655
Eddy loss K*((V)^2)/2*g
Where:
C = 100 assm.'d; d = 5.761" K = 0.1
q = GPM V = FPS
Brine Friction Multiplier 1.36

To Point	GPM	Length	f rate Ft/100'	Friction Loss	Sect. Vel.	h loss @ hole
1	400	3	2.7	0.08	4.9	0.04
2	369	3	2.3	0.07	4.5	0.03
3	339	3	2.0	0.06	4.2	0.03
4	308	3	1.7	0.05	3.8	0.02
5	278	3	1.4	0.04	3.4	0.02
6	247	3	1.1	0.03	3.0	0.01
7	217	3	0.9	0.03	2.7	0.01
8	186	3	0.7	0.02	2.3	0.01
9	155	3	0.5	0.01	1.9	0.01
10	125	3	0.3	0.01	1.5	0.00
11	94	3	0.2	0.01	1.2	0.00
12	64	3	0.1	0.00	0.8	0.00
13	33	3	0.0	0.00	0.4	0.00
				0.41		0.18

Hdr. Loss=(Frict. Loss + h Loss)*Brine Mult. = 0.81

Orifice Flow Check Where Q=C*a*(2*g*H)^0.5

1st Orifice = 0.0338 CFS = 15.2 GPM
Last Orifice= 0.0338 CFS = 15.2 GPM

Subject: Design ANALYSIS - Brine Pipe System MATERIAL SELECTION	Project No. 89C 114 MM
By WWI	Task No. 513
Checked By Joseph Scott	File No. 2
Date 6/1/92 Date 6/2/92	Sheet 1 of 1

Design Criteria

1. Should not corrode during the short term operation
2. Should not erode during the operation.
3. Must not weaken at expected temperature.
4.

Conditions for Design Basis

1 Maximum fluid temperature will be <160°F
2 Amount of solids in the fluid stream is unknown
3 Fluid is extremely corrosive.

TYPE OF SYSTEM

Open piping system

TYPE OF EQUIPMENT

Considered:

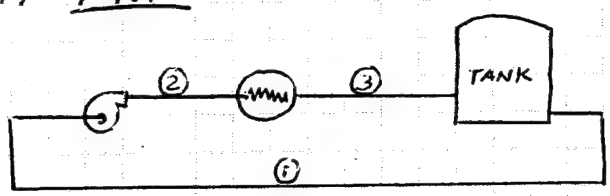
Carbon Steel - Known to corrode

Stainless steel - Is attacked by this fluid and is expensive.

HDPE - Would not corrode, may erode, and expected fluid temperature, may soften pipe

FRP - Would not corrode, would not erode, could take the expected temperature, and has been used elsewhere for handling this fluid.

Selection: FRP



400 gpm flow

1 Keep SUCTION LINE SHORT - Connect to existing tank outlet connections
2 Pump to Heat Exchanger to be skid mounted
3. Maximum temperature leaving heat exchanger to be <160°F

CALCULATIONS

Recommended fluid velocity is 4 to 7 FPS for a drain line.
(Ref: Carrier Design Manual, Part 3, Table 13)

ID of 6" Fibercast III = 6.625" OD - (.118 + .088)x2 = 6.213" = .21 SF Ft.

$$\frac{400 \frac{gal}{min}}{7.4805 \frac{gal}{Ft^3}} = 53.47 \frac{Ft^3}{min} \times \frac{1\ min}{60\ sec} = 0.89 \frac{Ft^3}{sec}$$

$$\frac{.89\ Ft^3/sec}{.21\ Ft^2} = 4.23\ FPS$$

6" is OK for velocity.

Subject BRINE BYPASS VALVE SELECTION

Project No. 89C 114 MM

Task No. 5

By WWI

Checked By JPS

File No. 2

Date 6/10/92

Date 6/24/92

Sheet 1 of 1

TOTAL BRINE FLOW = 400 GPM

BRINE FLOW THRU HX = 167 GPM @ 15 PSI

BRINE BYPASS FLOW 233 GPM

FROM DIA-FLO DIAPHRAGM Valve Catalog Pg. 67 & 71

$$C_V = Q_a \sqrt{\frac{SG}{\Delta P}}$$

$$C_V = 233 \sqrt{\frac{1.2}{15}}$$

$$C_V = 66$$

A DIA FLO WEIR Body Pattern - 2½" Flanged End - Hard Rubber Lined has a CV = 80 @ 50% open and CV = 65 @ 40% open

Use a 2½" valve for Bypass

Subject Brine Pump Selection - Design Analysis		Project No. 89C-114MM	
By WWI	Checked By Joseph Scott	Task No. 5.3	
		File No. 3	
Date 6/1/92	Date 6/3/92	Sheet 1	of 2

Design Criteria

1. 800 GPM Total recirculation rate
2. Highly Corrosive fluid
3. 140°F maximum fluid pumping temperature
4. Ok if seal flushing fluid leaks into the brine system
5. Operating life - 1 week

Design Conditions

1. 4.23 FPS brine velocity thru piping system
2. Brine - 1.2 sp.gr ; 74.9 #/Ft³ ; 10 #/gal
3. Brine Abs. Visc = 4.5 cp @ 70 (almost like water).
4. 400 GPM flow per pump
5. Pressure at header entrance 10.60 Ft of brine
6. Heat exchanger Pressure loss 29 Ft. of brine

Type of System - "Open" system handling highly corrosive & toxic fluid

EQUIPMENT SELECTION

Considered

1. Hose pump - No good - Largest size is too small
2. Rotary Lobe - No good - Largest size is too small
3. Progressive Cavity - Capacity & Head are OK
   Can be made of corrosion resistant alloys, but expensive
   Can be made of Stainless steel which will corrode
   Still expensive, but will last for operation
   Expensive relative to other types ≈ $20,000
4. ANSI Fiberglass - Capacity & Head ok at 1150 RPM - good slow spd.
   Will not corrode
   Erosion is a concern, but impeller can be provided with a hardened surface to reduce erosion rate

PUMP TYPE SELECTION - ANSI Fiberglass

CONTROL - Manual operation
Low seal flushing pressure will automatically stop pump

Subject: Design Analysis - Brine Pump Selection | Project No. 89C 114 MM

By: WWF | Checked By: JPS | Task No. 5.3

File No. 3

Date: 6/2/92 | Date: 6/3/92 | Sheet 2 of 2

CALCULATIONS

Reynolds No. $R_e = \dfrac{7740 \times d \times V \times sp.gr}{\mu}$

Where
d = pipe ID in inches = 6.213
μ = abs. visc. in centipoises
V = pipe velocity = FPS
SP.GR = 1.2
ϵ = rel. roughness = .009 (assumed)

$R_{e_b} = \dfrac{7740 \times 6.213 \times 4.23 \times 1.2}{4.5} = 5.4 \times 10^4$

From ~~friction~~ Renolds No. Charts $f_b = .025$

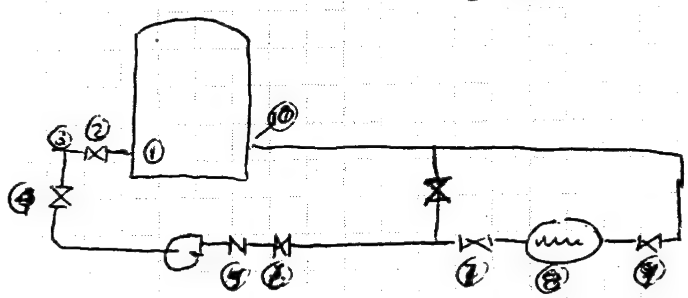
$R_{e_w} = \dfrac{7740 \times 6.213 \times 4.23 \times 1}{.98} = 2.07 \times 10^5$

from Reynolds No. Charts $f_w = .022$

Friction Loss multiplier $= Sp.gr. \times \dfrac{f_b}{f_w}$

$= 1.2 \times \dfrac{.025}{.022}$

$= 1.36$



ITEM No.	Element	Calc	EQ Lgth	Ft. HD Loss
1	Tank outlet	$h = K\frac{V^2}{2g}$ where K=.5		.14
2.	gate valve		3.2	
3.	Side outlet Tee		40.0	
4.	gate valve		3.2	
5.	Check valve		39.0	
6.	gate valve		3.2	
7.	gate valve		3.2	
8.	Ht. Exchg			29
9.	gate valve		3.2	
10.	Press at Hdr			7.25
-	Straight Pipe		150	
-	Elbows (10)		102	
	45 Elbows 3		21.3	
			368'	36.4'
	Friction factor from vendor data		11'/100'	
			4.05'	

SYSTEM LOSSES

PIPING	4.05
Tank outlet	.14
Heat Exch	29.00
Header	10.60
	43.80
Brine mult	1.36
	59.6
Safety Fact	1.1
	65 Ft

Selection - 4x6x13 Pump @ 1150 RPM with 12 3/4" impeller @ 70% eff
@ ≈ 12.3 BHP Say 20HP motor

Woodward-Clyde Consultants

Subject DESIGN ANALYSIS - Heat Exchanger

By WWI

Date 6/1/92

Checked By Joseph Scott

Date 6/3/92

Project No. 89C 114 MM

Task No. 5.3

File No. 4

Sheet 1 of 1

Design Criteria

1. Heat 1,504,000 # of fluid in about 24 Hrs
2. Heat exchange surface subject to severely corrosive fluid
3 Keep pressure drop thru heat exchanger to 10 to 15 psi range
4. Heat exchange area to be small as practical, but fluid passages to be "generous."
5. Heater fluid temperature to 90 to 300°F for quick heatup
   Reduce heater fluid temperature once target temperature is attained
6. Passages must be cleanable

Design Conditions

1. Tank fluid temperature at start of heatup	40°F
2. Maximum TANK Fluid Temp	140°F
3. Maximum Fluid temperature leaving heat exchanger	160°F
4. Total fluid flow though not necessarily thru the exchanger	400 GPM
5 Brine Specific gravity	1.2
6. Brine Specific heat	0.93
6. Brine Viscosity at 70°F	4.5 CP

TYPE of System. Fluid to fluid heat exchange

TYPE of Equipment

Considered

Spiral type heat exchanger - Hastelloy would meet all requirements
Double tube " " " " " " "
Plate/Frame " " Temp. range for this type is not good
We could operate at a lower temperature
but would then have to increase area,
and thus the cost
Sealing between fluids is more of a problem

SELECTION - Spiral or Double tube
Base design layout on spiral with
hastelloy heat transfer service

CALCULATION.
I contacted a vendor with the requirements and he came back with a selection for a single heat exchanger instead of two as requested. Subsequent conversation indicates that the heat transfer area and flows would be half of that shown, but the pressure drop would be the same.

CONTROLS - provided to assure that brine temperature does not exceed 160°F. Assumption is that as brine temperature approaches 140°F, operator will reduce heater fluid temp.

ALFA-LAVAL THERMAL	SPIRAL HEAT EXCHANGER SPECIFICATION SHEET	DATE: 92-05-12 ITEM NO: TYPE: H PLATE AREA: 205 ft2
CUSTOMER: WOODWARD CLYDE PLANT LOCATION: SERVICE:		CUST REF: A-L REF: 92-7-4845 QUOTE/CALC NO:

Number of units connected in parallel/series 1/1

DUTY REQUIREMENTS per unit			HOT SIDE	COLD SIDE
Fluid			BRINE	DOWTHERM
Total fluid quantity		lb/h	200000	300000
Temperature	In	'F	50.0	300.0
	Out	'F	85.0	251.8
Pressure drop	Perm/Calc	psi	20/ 15	20/ 12

PHYSICAL PROPERTIES				
Density	In/Out	lb/ft3	70/ 70	56/ 56
Heat Capacity	In/Out	Btu/lb,'F	0.930/0.930	0.450/0.450
Viscosity	In/Out	cP	4.500/4.500	1.000/1.000
Thermal Cond.	In/Out	Btu/ft,h,'F	0.300/0.300	0.080/0.080

PERFORMANCE DATA		
Heat Exchanged	kBtu/h	6502.3
Flow direction		Countercurrent
Overall H.T.C. Service	Btu/ft2,h,F	175.2
Fouling Resistance*10000.	FT2,H.F/BTU	3.00
Excess Surface	%	1.9
Net Heat Transfer Area	ft2	178.2

CONSTRUCTION DATA			
Flange Standard			
Cylindrical Width	in	48.00	
Outer Diameter	in	23.50	
Plate Material		HASTELLOY C276	
Channel Closure		open-roll	open-roll
Design Overpressure	psig	100.0	100.0
Design Temperature	'F	500.0	500.0
Connection Size	in	4.0	6.0

ADDITIONAL DATA			
Fluid Volume	ft3	4.94	6.36
Weight Empty/Operating	lb	2140/ 2840	
Shipping weight	lb		
Shipping volume	ft3		
Width / Length/ Height	in	/ /	

D. W. DAIGLER COMPANY

2055 S. Oneida, Suite 370
Denver, Colorado 80224

Phone: (303) 757-4981
FAX: (303) 692-8751

TO WOODWARD-CLYDE DATE 5/12/92
ATTN. BILL IRVING 694-3946 PAGE 1 OF 2
SUBJECT BRINE HEATER - Spiral Alfa Laval

Attached is new design. (205 ft^2)

- Unit will heat 1,504,000 lb of Brine from 50° to 140° in 24 hrs. ΔP_{Brine} = 15 psi, $\Delta P_{Dowtherm}$ = 12 psi.
- Hot Side is 300°F Dowtherm - flowing at 300,000#/hr.
- Max. wall temperature is 158°F (Kept below 160°F)
- Price = Hastelloy C276 = $48,000. each
  = 316SS = 22,500. each
- Dimensions - use existing print for reference.

Please call with any questions.

Thank you.

Charlie Dobos

Thanks for your patience.

Conversation w/ C. Dobos
With 2 Ht. Exch.
½ Brine & Oil Flow
ΔP will be the same
Ht. Exch Area will be ½
Same overall HTC coefficient
Config. will be same
but 4" connections

Brine will connect Hot Side
Oil will connect cold side
Price for 2 will be 130% of
one large unit

(DWG-OOC-024)

31

Subject DESIGN ANALYSIS - Thermal Fluid Piping

Project No. 89C-114MM

By WWI

Checked By Joseph Scott

Task No. 5.3

File No. 5

Date 6/2/91

Date 6/3/92

Sheet 1 of 1

Design Criteria

1. Select heater that will not require a stationary engineer to operate
2. Temperature of the fluid selected at 300°F
3. Fluid circulation rate to be 300000 #/HR per heat exchanger selection
4. Heater can be purchased but preferably rented if available
5. Since heater will be outside "bermed" area, we must avoid any fluid transfer of brine to oil.
6. Piping must be able to transport 300°F and possible rough handling

Design Conditions

1. Fluid Selection - Therminol 55

   SP. GR = 48.5 #/FT^3 = 0.78

   SP. HT = 0.55 BTU/#°F

   Thermal Conductivity = 0.06 Btu/FT-HR-F

   Viscosity 2.7 CP

   Fluid temp 300°F

Type of System

Considered

Hot water - would need stationary engineer as it is high pressure

Steam " " " " for the steam

Thermal fluid - low pressure system - Skid mount unit available. Also however, the oil field industry uses mobile hot oil heaters and there is a good chance we could rent this

SELECTION - Thermal fluid - Carbon steel piping

CALCULATIONS

STR. PIPE @ 6" = 200'

Elbows @ 6" = 8

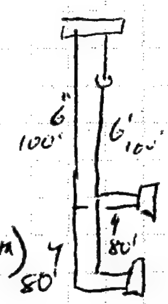
Tees @ 6" 1

Str. Pipe @ 4" 160'

Elbows @ 4 = 5

Tees @ 4" = 1

(Assum. fittings add 50% to length of pipe system)



PIPING - 300000 #/HR = 667 GPM

$$Re = \frac{3162 \times Q}{d \times K}$$

from Cameron pg. 92

where $K = \frac{ABS.VISC}{SP.GR} = \frac{2.7}{.78}$

$K = 3.46$

$$R_e = \frac{3162 \times 667}{6.065 \times 3.46}$$

$R_e = 1 \times 10^5$ for 6" pipe

$f = .0195$

$$R_e = \frac{3162 \times 333.5}{4.026 \times 3.46}$$

$R_e = 7.5 \times 10^4$ for 4" pipe

$f = .021$

Head LOSS CALCULATION

$$h = \frac{.03112 \times f \times L \times Q^2}{d^5}$$

$$h_6 = \frac{.03112 \times .0195 \times (200 \times 1.5) \times 667^2}{(6.065)^5}$$

$h_6 = 9.87'$

$$h_4 = \frac{.03112 \times .021 \times (160 \times 1.5) \times (333.5)^2}{(4.026)^5}$$

$h_4 = 16.5'$

TOTAL = 6" PIPE 10'

4" PIPE 16.5'

HT. EXCH. 31'

CONTROL = 15'

72.5 x 1.2 = 87' say 90'

Subject DESIGN ANALYSIS - HEAT SOURCE | Project No. 81C 114 MM
By WWI | Checked By Joseph Groff | Task No. 5.3
File No. 6
Date 6/1/92 | Date 6/3/92 | Sheet 1 of 1

Design Criteria

1 HEAT CAPACITY of ≈ 6 MBH
2. Circulate ≈ 660 GPM of thermal fluid
3. Packaged equipment - mobile rented equipment acceptable.

DESIGN CONDITIONS

1. Heat required is ≈ 5 MBH + pickup losses - say 6 MBH
2 Supply fluid at 300°F

Type of equipment - Hot oil heater supplying Therminol 55

CONTROL System to include control equipment as described in the attached letter

Control intent is to reduce the fluid temperature as tank fluid approaches 140°F

CALCULATIONS - LOAD CALCULATIONS HAVE BEEN PERFORMED ~~the~~ IN File No.'s 1-5 - CONDITIONS ARE:

LOAD 6,000,000 Btuh
Circulation rate 660 GPM @ ≈ 90' Head
Fluid Temperature 300°F
Fluid = Therminol 55
SP. GR = 0.78
SP. Ht. 0.55 Btu/#°F
Viscosity = 2.7 CP

Subject: PROPANE PIPE SIZE

Project No. 89C 114 MM

By WWI

Checked By JPS

Task No. 6

File No. 6

Date 6/9/92

Date 6/24/92

Sheet 1 of 1

PROPANE

No. Am. Comb. Handbook

Formula C_3H_8 — Pg. 299

ABS. VISC = 80 CP @ 100 = 5.5×10^{-5} lb/ft·s — Pg. 241

Htg. Value = 2322 Btu/Ft³ — Pg. 8

gas gravity = 1.52 at STP — Pg. 37

Pressure DROP formula $\Delta P = 43.5\, f \times \frac{L}{d^5} \times \rho \times Q^2$

Where

f = Dependent on Reynolds NO

$L \approx$ 50 Ft

d = 2.067" for 2" pipe

$\rho = .076\ \#/ft^3 \times 1.52 = .114\ \#/ft^3$

Q = Heat input / Ht. Value $= \frac{7{,}734{,}000\ Btu/HR}{2322\ Btu/Ft^3} = 3330\ \frac{Ft^3}{HR} = 55.5\ \frac{Ft^3}{min} = .925\ \frac{Ft^3}{sec}$

$R = \frac{\rho \times V \times D}{\mu} = \frac{.114 \times V \times D}{5.5 \times 10^{-6}}$

where

$V = \frac{.925\ Ft^3/sec}{.02330\ Ft^2} = 39.7\ FPS$

$D = .1722\ Ft$

$R = \frac{.114 \times 39.7 \times .1722}{5.5 \times 10^{-6}} = 141{,}700$

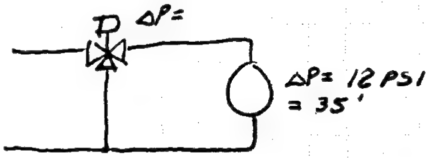
FROM Pg. 159 ∴ $f = .021$

$\therefore \Delta P = 43.5 \times .021 \times \frac{50}{2.067^5} \times .114 \times (.925)^2$

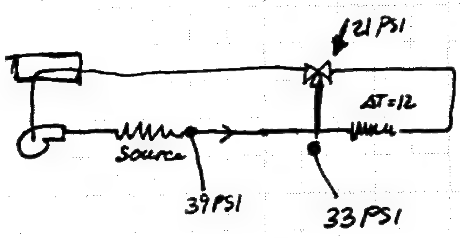
$\Delta P = .118\ PSI = .272\ Ft_{H_2O} = 3\tfrac{1}{4}"\ H_2O$

sister
pete Simner
860-8600

Subject: Thermal Fluid Bypass Valve Sizing		Project No. 89C 114 MM	
By: WWI	Checked By: JPS	Task No. 6	
		File No. 5	
Date: 6/17/92	Date: 6/24/93	Sheet 1	of



1. Valve pressure drop should ~~50~~ 70% of difference between supply & Return main pressure unless the 70% drop exceeds 50% of abs. upstream pressure



6" Head loss to heat exch. 10'
4" Head loss to heat exch. 8'
18' = 6.25 PSI

Press. @ Bypass = 33 PSI
Press. @ Valve Jct. 21 PSI
ΔP between lines 12 PSI

$0.7 \times 12 = 8.4$ PSI to 6 PSI
say ≈ 7 PSI

GPM = 333 = Q_a
SG = 0.8 sp.Gr.
ΔP = 7 PSI

$$C_V = Q_a \sqrt{\frac{SG}{\Delta P}}$$

$$C_V = 333 \sqrt{\frac{.8}{7}}$$

$$C_V \approx 112$$

Subject Tank 102 Heat Transfer Calculations
Project No. 89C114MM
Task No. 5
File No.
By J. Scott
Checked By WWG
Date 5-5-92
Date 6/2/92
Sheet 1 of 3

As result of 30% design review meeting on 5/4/92 design basis is changed.

Heating and mixing in Tank 102 to dissolve crystals will now take place after removal of as much Basin F liquid as possible through bottom outlet on Tank 102

New design basis for volume of liquid to be heated in Tank 102:

From Treatment Assessment Report for case where Basin F liquid drained from crystals

volume crystals (2.6' depth) = 470 yd³

Volume water required = 200 gal/yd³

Resulting total volume = 320 gal/yd³

Volume water required = 94,000 gal

Volume liquid = 150,400 gal

Run heat balance calculations using Fortran program as before:

Volume liquid = 150,400 gal
Ambient temperature = 40 °F
Initial liquid temperature = 40 °F
Air leakage into tank = 1100 cfm
No insulation
Constant heat inputs of 2,500,000 Btu/hr
5,000,000 Btu/hr

Results of runs attached.

Select 5,000,000 Btu/hr heat input as design basis. Will heat liquid to 140 °F in ~30 hours
At 140 °F require ~1,800,000 Btu/hr to maintain temperature

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SUBJECT: TANK 102 HEAT BALANCE CALCULATIONS PROJECT NO.: 89C114MM
BY: J. SCOTT CHECKED BY: DVG TASK NO.: 5
DATE: 5-5-92 DATE: 6/2/92 SHEET: 2 of 3

RESULTS OF HEAT BALANCE FOR TANK 102

INPUT DATA:

VOLUME LIQUID IN TANK, GAL = 150400.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
NO INSULATION ON TANK WALL
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 2500000.

CALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

		AVG. HEAT LOSS TERMS, BTU/HR			
TIME (HR)	TEMPERATURE (F)	LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	14.	6.	4.	0.
2.4	45.0	5404.	17820.	12306.	80.
5.0	50.0	18640.	57418.	39983.	258.
7.6	55.0	33767.	99303.	68211.	460.
10.3	60.0	51999.	141128.	97425.	692.
13.1	65.0	69286.	184697.	127389.	958.
16.1	70.0	86911.	228056.	156780.	1261.
19.2	75.0	106225.	271867.	187335.	1609.
22.5	80.0	124592.	316399.	217338.	2007.
25.9	85.0	143500.	360631.	247656.	2463.
29.6	90.0	162948.	405344.	278289.	2985.
33.5	95.0	183645.	450854.	309445.	3584.
37.6	100.0	204241.	495868.	340276.	4270.
42.0	105.0	225377.	541243.	371343.	5056.
46.8	110.0	247054.	586979.	402114.	5958.
52.0	115.0	267313.	633076.	433615.	6993.
57.7	120.0	289934.	678601.	464741.	8180.
64.0	125.0	310868.	724367.	496025.	9542.
71.0	130.0	332072.	771427.	527467.	11106.
78.9	135.0	356044.	816622.	559067.	12902.
88.1	140.0	377923.	863110.	590824.	14965.
99.1	145.0	399380.	910147.	622132.	17335.
112.5	150.0	421766.	956485.	653751.	20058.
130.0	155.0	444421.	1003003.	685489.	23189.
155.2	160.0	467347.	1049702.	717344.	26788.
162.1	161.0	482532.	1077949.	736606.	29202.

SUBJECT: TANK 102 HEAT BALANCE CALCULATIONS | PROJECT NO.: 89C114MM
BY: J. SCOTT | CHECKED BY: WWS | TASK NO.: 5
DATE: 5-5-92 | DATE: 6/2/92 | SHEET: 3 of 3

RESULTS OF HEAT BALANCE FOR TANK 102

INPUT DATA:

VOLUME LIQUID IN TANK, GAL = 150400.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
NO INSULATION ON TANK WALL
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 5000000.

CALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

		AVG. HEAT LOSS TERMS, BTU/HR			
TIME (HR)	TEMPERATURE (F)	LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	14.	6.	4.	0.
1.2	45.0	5404.	17820.	12306.	80.
2.4	50.0	18640.	57418.	39983.	258.
3.7	55.0	33767.	99303.	68211.	460.
5.0	60.0	51999.	141128.	97425.	692.
6.3	65.0	69286.	184697.	127389.	958.
7.6	70.0	86911.	228056.	156780.	1261.
9.0	75.0	106225.	271867.	187335.	1609.
10.4	80.0	124592.	316399.	217338.	2007.
11.8	85.0	143500.	360631.	247656.	2463.
13.2	90.0	162948.	405344.	278289.	2985.
14.7	95.0	183645.	450854.	309445.	3584.
16.2	100.0	204241.	495868.	340276.	4270.
17.8	105.0	225377.	541243.	371343.	5056.
19.4	110.0	247054.	586979.	402114.	5958.
21.0	115.0	267313.	633076.	433615.	6993.
22.7	120.0	289934.	678601.	464741.	8180.
24.5	125.0	310868.	724367.	496025.	9542.
26.2	130.0	332072.	771427.	527467.	11106.
28.1	135.0	356044.	816622.	559067.	12902.
30.0	140.0	377923.	863110.	590824.	14965.
32.0	145.0	399380.	910147.	622132.	17335.
34.0	150.0	421766.	956485.	653751.	20058.
36.1	155.0	444421.	1003003.	685489.	23189.
38.3	160.0	467347.	1049702.	717344.	26788.
38.8	161.0	482532.	1077949.	736606.	29202.

Subject: Tank 102 Heat Transfer Calculations
Project No. 89C114MM
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By J. Scott
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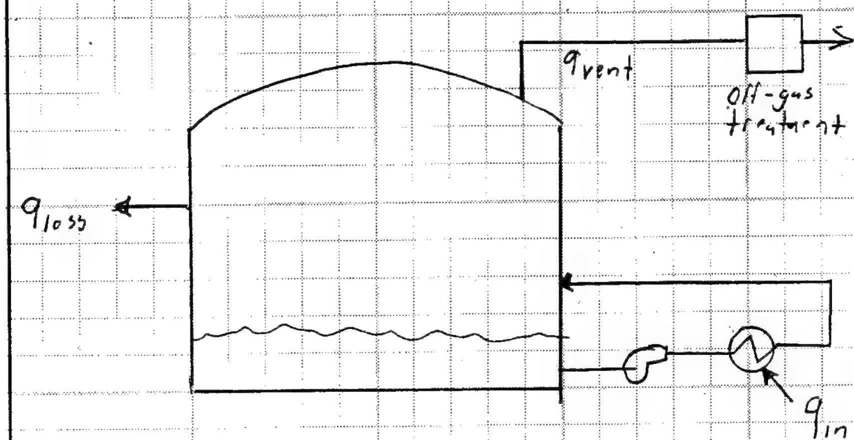
Sheet 1 of 32

Heat transfer calculations for Tank 102 for design basis of tank liquid heating system.



Recirculate liquid through heating system and add heat at q_{in} Btu/hr

Maintain tank head space at negative pressure by using fan to draw gas through tank vent and treatment system. Volume of gas removed will be volume which leaks into tank through seams in tank cover. Will result in loss of heat equal to q_{vent}

Will lose additional heat through tank wall and cover. Loss through tank base will be negligible. Total rate of heat loss q_{loss}

Once final liquid temperature is reached rate of heat input q_{in} must equal the sum of heat loss terms q_{loss} + q_{vent}. During period of heating of liquid additional heat must be added to increase liquid temperature.

Must provide calculated estimates for terms in heat balance equation

Subject: Tank 102 Heat Transfer Calculations

By: J. Scott

Date: 4-28-92

Checked By: WWS

Date: 6/2/92

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$$V \rho C \frac{dT}{d\theta} = q_{in} - q_{loss} - q_{vent} \qquad (1)$$

C = specific heat capacity of liquid, Btu/lb-°F
V = volume of liquid in tank, gallons
ρ = liquid density, lb/gal
T = liquid temperature, °F
θ = time, hrs
q_{in} = heat input, Btu/hr
q_{loss} = heat loss through tank wall and cover, Btu/hr
q_{vent} = heat loss through tank vent, Btu/hr

Assumes that heat capacity of tank wall and roof, and heat capacity of air in tank head space is negligible compared to heat capacity of liquid. Check assumption

Liquid volume in tank ≃ 254,000 gallons

Liquid density ≃ 8.33 × 1.2 = 10.0 lb/gal

Liquid specific heat ≃ 0.8 Btu/lb-°F

Liquid heat capacity ≃ 254,000 × 10.0 × 0.8 = 2,032,000 Btu/°F

Heat capacity of air in tank:

Air volume = ?

Head space up to straight wall height of tank:

(40′ wall height − 7′ liquid depth)(π/4)(78.5′)²
= 159,714 ft³

Add'l head space in dome cover

13′-1″ maximum height in center. Apply factor of 1/2

(13.08′) × 1/2 × π/4 × (78.5′)² = 31,652 ft³

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Subject Tank 102 Heat Transfer Calculations
Project No. 89C114MM
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By J. Scott
Checked By [illegible]
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Total air volume = 191,400 ft^3

Typical mid-range density and specific heat of moist air at 100 °F

$\rho = 0.0663$ lb/ft^3
$c = 1.75$ Btu/lb-°F

Approximate heat capacity of head space =

191,400 × 0.0663 × 1.75 = 22,207 Btu/°F

Head space air heat capacity ≃ 1% of liquid heat capacity. Can neglect.

Heat capacity of tank wall and cover:

Specific heat steel = 0.12 Btu/lb-°F

Specific heat aluminum = 0.21 Btu/lb-°F

Approx. total tank wt = 553,000 lbs

Assume aluminum cover is 20% of total wt.

Heat capacity = 0.8 × 553,000 × 0.12 + 0.2 × 553,000 × 0.21 = 76,314 Btu/°F

Tank wall and cover heat capacity ≃ 3.8% of liquid heat capacity. Can neglect.

Conduct Heat Balance Calculations

General Assumptions:

1) Energy required to heat tank wall and cover and air in tank head space is negligible compared to energy required to heat liquid.

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Subject: Tank 102 Heat Transfer Calculations

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By J. Scott

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Date 4-28-92

Date [illegible]

2) Air in tank head space is always at same temperature as liquid in tank and is at 100 % humidity

3) Current SQI operation schedule suggests operation will take place during summer. However, changes in SQI schedule could change operation to fall or early winter. Use ambient conditions of 7.5 mph wind and 40 °F average temperature for conservative design of heat system

4) Assume liquid in tank is initially at average ambient temperature of 40 °F

5) Heat loss occurs through radiation and convection to ambient air from outer skin of tank wall and cover

6) Heat is removed through operation of tank head space vent system. Calculations conducted for vent treatment system design concluded that rate of air leakage into tank through seams in cover is 1100 ft³/min at 40 °F. Assume this displaces an equal amount of head space air at tank liquid temperature and 100 % humidity.

7) Final target temperature of liquid is 140 °F (60 °C) based on results presented in Alternatives Assessment Report. Will heat liquid to 140 °F and maintain at this temperature.

Solve for terms in heat balance equation (1) presented on sheet #2

$$V \rho C \frac{dT}{d\theta}$$

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Subject: Tank 102 Heat Transfer Calculations
Project No. 89C 114 MM

Task No. 5

By J. Scott
Checked By [illegible]

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Sheet 5 of 32

Term accounts for energy required to heat liquid from initial temperature to final temperature.

V = volume liquid in tank, gallons (independent variable)

ρ = density of liquid, lb/gallon. For specific gravity 1.2 = 10.0 lb/gal

C = specific heat of liquid, Btu/lb-°F. For brine solution = 0.8 Btu/lb-°F

T = liquid temperature at any time, °F

θ = elapsed time, hours

q_{vent}

Term accounts for heat removed by venting of head space in tank.

Air enters at 40°F and exits at tank liquid temperature and 100% relative humidity.

$$q_{vent} = S_{40°F} \times \rho_{40°F} \times (h_T - h_{40°F})$$

q_{vent} = heat loss through gas venting, Btu/hr

S = rate of air leakage into tank, cfm. Entering air at 40 °F. $S_{40°F}$ = 1100 cfm

$\rho_{40°F}$ = density of air at 40 °F = 0.0639 lb dry air/ft^3

$h_{40°F}$ = enthalpy of air at 40 °F = 16.6 Btu/lb dry air

h_T = enthalpy of moist air at tank liquid temperature T, Btu/lb dry air

Equation developed for enthalpy of moist air over temperature range 40 °F to 140 °F

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Subject: Tank 102 Heat Transfer Calculations | Project No. 89C114MM
By: J. Scott | Checked By: WWG | Task No. 5
Date: 4-25-92 | Date: 6/2/92 | File No.
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$$h_T = \exp(1.7742856887 + 0.0259026855 \times T + 0.0000053392 \times T^2)$$

Equation developed using data in psychrometric tables. Maximum percent error over range 40 °F to 140 °F is 2.4 %. Calculations attached as sheet #7

Equation also developed for air density using data in psychrometric tables to allow variation in ambient air temperature if needed.

$$\rho = 0.0655243556 + 6.53117 \times 10^{-6} \times T - 1.19101 \times 10^{-6} T^2$$

Maximum percent error over range 40 °F to 140 °F is 0.84 %. Calculations attached as sheet 8

Estimation of heat loss terms. Heat loss will occur through radiation and convection from outer surface of tank wall and cover. Will be three cases to estimate

1. Tank wall at height at and below level of liquid in tank
2. Tank wall at height above level of liquid in tank.
3. Tank cover

Case 1. Tank wall up to height of liquid level in tank.

Must account for series of resistance to heat transfer. Make allowance for including a layer of insulating material on exterior of tank.

Subject:	Tank 102 Heat Transfer Calculations			Project No.	89C114M
By	J. Scott	Checked By	WWJ	Task No.	5
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EQUATION FOR ENTHALPY OF MOIST (100 % HUMIDITY) AIR

T = TEMPERATURE, F
H = ENTHALPY, BTU/LB DRY AIR (from psychrometric tables)

T	H	H CALC	% ERROR
40	16.37	16.759005843	2.376%
50	21.99	21.818710494	-0.779%
60	28.93	28.436337584	-1.706%
70	37.67	37.100690878	-1.511%
80	48.82	48.45672815	-0.744%
90	63.22	63.356318101	0.216%
100	82.1	82.925773028	1.006%
110	107.09	108.655791763	1.462%
120	140.64	142.52136956	1.338%
130	186.45	187.14181942	0.371%
140	250.82	245.99453668	-1.924%

HCALC = EXP(A + B*T + C*T*T)

A =	1.7742856887
B =	0.0259026855
C =	0.0000053392

Subject:	Tank 102 Heat Transfer Calculations		Project No. 89C114MM
By	J. Scott	Checked By ZWP	Task No. 5
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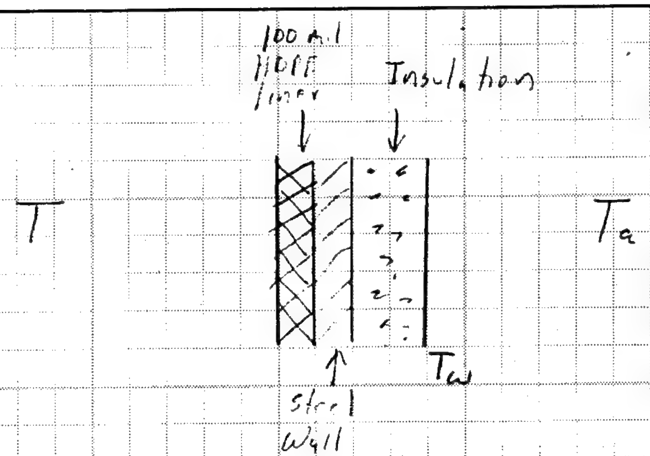
EQUATION FOR DENSITY OF MOIST (100% HUMIDITY) AIR

T = TEMPERATURE, F
RHO = DENSITY, LB DRY AIR/FT**3

T	RHO	RHO CALC	% ERROR
40	0.06442	0.06388	-0.838%
50	0.0629	0.06287	-0.042%
60	0.06135	0.06163	0.454%
70	0.05975	0.06015	0.662%
80	0.05805	0.05842	0.645%
90	0.05623	0.05647	0.418%
100	0.05423	0.05427	0.069%
110	0.05201	0.05183	-0.343%
120	0.04952	0.04916	-0.732%
130	0.04669	0.04625	-0.952%
140	0.04346	0.04309	-0.840%
150	0.03974	0.03971	-0.085%
160	0.03545	0.03608	1.776%

RHO CALC = A + B*T + C*T*T

A = 0.0655243556
B = 6.53147E-06
C = -1.19101E-06



Heat transfer away from outer layer of tank wall at height below liquid level.

$$q_{loss} = UA(T_w - T_a)$$

q_{loss} = rate of heat loss from tank to ambient air, BTU/hr
U = overall heat transfer coefficient for outer wall due to convection and radiation BTU/ft² °F-hr
A = surface area for transfer [illegible] ft²
T_a = ambient air temperature, °F
T_w = temperature of outer surface, °F
T = temperature of liquid, °F
Thickness of liner, tank wall, and insulation <<< diameter of tank and so can treat layers as flat plate

A, area for transfer:

height of liquid in tank for liquid volume V, gallons

$$ht = 4 \times (V / 7.481\ ft^3/gal) / (\pi \times 78.5' \times 78.5')$$

$$A = \pi \times (78.5')(ht)$$

$$A = 4 \times (V/7.481)/78.5 = 0.006811 \times V$$

Heat transfer coefficient includes terms for convection and radiation

$$U = h_{rad} + h_{conv}$$

Subject: Tank 102 Heat Transfer Calculations
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By J. Scott
Checked By 2/29
File No.
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Radiation transfer coefficient from ASHRAE Fundamentals Handbook

$$h_{rad} = \frac{\epsilon \times 1.713\times10^{-9} \times ((T_a+459.6)^4 - (T_w+459.6)^4)}{(T_a - T_w)}$$

h_{rad} = radiation transfer coefficient, Btu/hr-ft^2-°F
ϵ = surface emissivity = 0.8

Convection transfer coefficient from ASHRAE Fundamentals Handbook

$$h_{conv} = C \times (1/24)^{0.2} \times \left(\frac{2}{T_a+T_w}\right)^{.181} (T_w - T_a)^{.266} \sqrt{1+1.277(wind)}$$

h_{conv} = convection transfer coefficient Btu/hr-ft^2-°F
C = equation constant = 1.394 for flat vertical wall
wind = ambient wind speed, mph

q_{loss} eqn includes unknown outer surface temperature, T_w. Heat loss to ambient air must equal heat transport through layers of tank wall

$$q_{loss} = UA(T - T_w)$$

Transfer area A is same as previous.

$$1/U = 1/h_{liner} + 1/h_{insulation}$$

U = Overall transfer coefficient, Btu/hr-ft^2-°F
h_{liner} = transfer coefficient for tank HDPE liner, Btu/hr-ft^2-°F
$h_{insulation}$ = transfer coefficient for tank insulation, Btu/hr-ft^2-°F

The resistance to heat transfer in the liquid next to the liner and through the steel wall will be negligible compared to these two resistances.

Thermal conductivity of HDPE = 2.7 Btu-in/hr-ft^2-°F
Liner thickness ~ 0.1 inch

h_{liner} = 27 Btu/hr-ft^2-°F

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Subject: Tank 102 Heat Transfer Calculations Project No. 89C114MM

By: JL Scott Checked By: 22W Task No. 5

File No.

Date: 4-28-92 Date: 6/2/92 Sheet 11 of 32

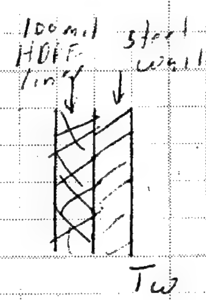
Thermal conductivity of fiberglass insulation = 0.6 Btu-in/hr-ft^2 °F
Insulation thickness, inches = δ

$h_{insulation} = 0.6/\delta$

The two equations for q_{loss} can be solved simultaneously to obtain the unknown terms q_{loss} and T_w

Case 2, Tank wall above height of liquid level in tank

Account for series of resistance to heat transfer. Do not include provision for insulation



Heat transfer away from outer layer of tank wall at height above liquid level

$q_{loss} = UA(T_w - T_a)$

Except for transfer area A terms and values for convective and radiation transfer coefficients are same as case 1.

Transfer area A:

Total wall area = $\pi \times 78.5' \times 40' = 9864.6$ ft^2

$A = 9864.6 - 0.006811\,V$

Subject: Tank 102 Heat Transfer Calculations — Project No. 89C 114MM

By: J. Scott — Checked By: [illegible] — Task No. 5

Date: 4-28-92 — Date: 6/2/92 — File No.

As before q_{loss} must be same as rate of heat flow through wall

$$q_{loss} = UA(T - T_w)$$

Transfer area A same

$$1/U = 1/h_{air} + 1/h_{liner}$$

U = overall coefficient, Btu/hr-ft^2-°F
h_{air} = transfer coefficient for air layer next to inside of tank liner, Btu/hr-ft^2-°F
h_{liner} = transfer coefficient for tank liner, Btu/hr-ft^2-°F
T = head space air temperature = liquid temperature, °F

Negligible resistance to heat transfer through steel wall

h_{liner} = 27 Btu/hr-ft^2-°F as for case 1

Air film transfer coefficient from ASHRAE Fundamentals Handbook for vertical wall

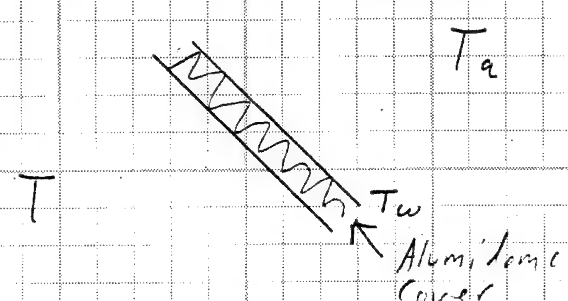
h_{air} = 1.47 Btu/hr-ft^2-°F

U = 1.39 Btu/hr-ft^2-°F

As before can simultaneously solve two equations for unknown T_w and q_{loss}

Case 3. Tank cover.

Account for series of resistances to heat transfer. [illegible] insulation



Subject Tank 102 Heat Transfer Calculations

Project No. 89C 114 MM

By J. Scott

Checked By ZZ9

Task No. 5

File No.

Date 4-28-92

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$q_{loss} = UA(T_w - T_a)$

q_{loss} = rate of heat loss from tank cover to ambient air, Btu/hr

U = overall heat transfer coefficient, Btu/hr-ft²-°F

T_w = temperature of outer layer of tank cover, °F

T_a = ambient air temperature, °F

T = head space air temperature = liquid temperature, °F

A = area of tank cover for heat transfer, ft²

Transfer area A:

Cover is made up of 105 plates of aluminum sheet. Each plate is an equilateral triangle of 11' 8 1/4" side.

Area per plate 1/2 bh $b = 11' 8 1/4" = 11.688'$
$h = b \sin 60° = 10.122'$

$1/2\,bh = 59.15\ ft^2$

$A = 59.15 \times 105 = 6211\ ft^2$

$U = h_{conv} + h_{rad}$

h_{conv} is same as for case 1 except substitute $C = 1.79$ as eqn constant for tank cover

h_{rad} is same as for case 1.

As before q_{loss} must be same as rate of heat flow through tank cover

$q_{loss} = UA(T - T_w)$

Transfer area A same

$U = h_{air}$

U = overall transfer coefficient, Btu/hr-ft²-°F

h_{air} = transfer coefficient for air layer next to inside of tank cover, Btu/hr-ft²-°F

Subject: Tank 102 Heat Transfer Calculations
Project No. 89C114MM
Task No. 5
File No.
By J. Scott
Checked By ZWG
Date 4-28-92
Date 6/2/92

Air film transfer coefficient from ASHRAE Fundamentals Handbook for tank cover

$h_{air} = 1.61$ Btu/hr-ft² °F

The two equations for q_{loss} can be solved simultaneously to obtain the unknown terms q_{loss} and T_w

Overall balance for Tank 102

$$V \rho c \frac{dT}{d\theta} = q_{in} - q_{loss} - q_{vent}$$

where q_{loss} is sum of loss terms for tank wall above and below liquid level and tank cover (Σ Cases 1, 2, 3)

If specify rate of heat input can calculate rate of increase of liquid temperature to 140 °F and rate of heat input required to maintain liquid at 140 °F.

A Fortran program was written to conduct the calculations and was run on a personal computer. The computer program listing is included with these calculations.

Input variables to program included

Initial liquid temperature, °F

Volume of liquid in tank, gallons

Ambient air temperature, °F

Rate of vent air leak into tank, cfm

Woodward-Clyde Consultants

Subject: Tank 102 Heat Transfer Calculations

By: J. Scott

Date: 1-28-92

Checked By: [illegible]

Date: 6/2/92

Project No.: 89C114MM

Task No.: 5

File No.:

Sheet 15 of 32

Thickness of fiberglass insulation provided on tank wall below liquid level, inches

Rate of heat input, Btu/hr

The computer program was used to estimate the time required to heat the liquid in tank 102 to 140°. The estimates were conducted assuming:

- 254,000 gallons liquid in tank
- 40 °F initial liquid temperature
- 40 °F ambient air temperature
- 1100 cfm air leakage into tank from venting

Calculations were conducted for constant heat input values of 5,000,000 and 10,000,000 Btu/hr. Calculations were conducted assuming [illegible] and 1 inch of fiberglass [illegible] level.

The results are attached and are presented in graphical and tabular form. The summary of results is

Heat Input	Insulation	Time to 140°F
5,000,000 Btu/hr	None	52.1 hours
10,000,000 Btu/hr	None	22.7 hours
5,000,000 Btu/hr	1 inch	48.2 hours
10,000,000 Btu/hr	1 inch	22.0 hours

Based on these results the design basis for the tank liquid heating system is 10,000,000 Btu/hr to allow the liquid to be heated in ~24 hours. The installation of insulation would not significantly reduce the heat-up time. The design basis for maintaining the tank temperature at 140 °F after heat-up will be a heat input of approximately 1,500,000 Btu/hr

Subject: Tank 102 Heat Balance Calculations
By. J. Scott
Date 4-28-92

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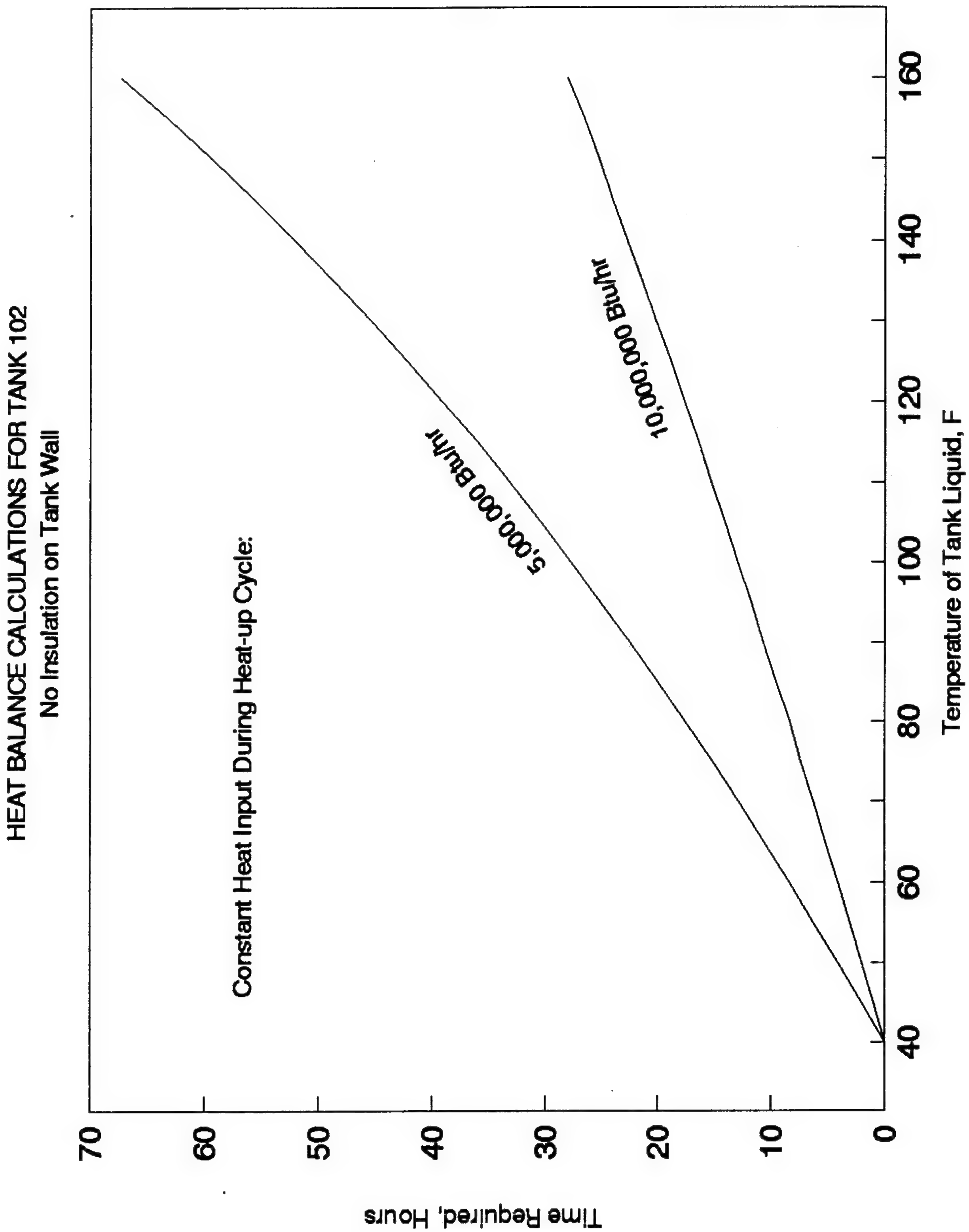
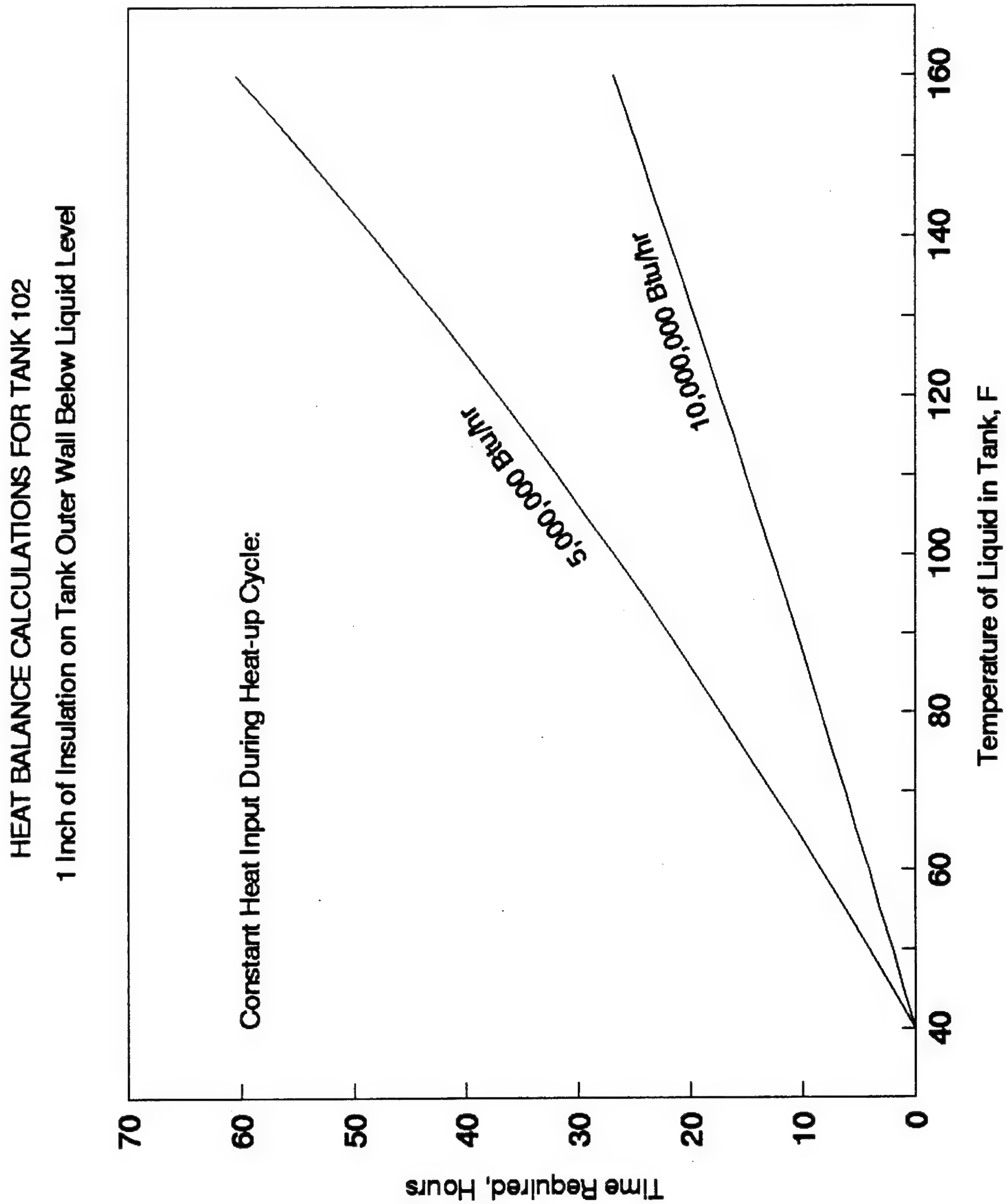


Subject: Tank 102 Heat Balance Calculations
By J. Scott
Date 4-28-92



ESULTS OF HEAT BALANCE FOR TANK 102

NPUT DATA:

VOLUME LIQUID IN TANK, GAL = 254000.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
NO INSULATION ON TANK WALL
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 5000000.

ALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

		AVG. HEAT LOSS TERMS, BTU/HR			
TIME (HR)	TEMPERATURE (F)	LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	23.	6.	4.	0.
2.0	45.0	9127.	16398.	12306.	80.
4.1	50.0	31480.	52835.	39983.	258.
6.3	55.0	57026.	91377.	68211.	460.
8.4	60.0	87818.	129863.	97425.	692.
10.6	65.0	117013.	169955.	127389.	958.
12.9	70.0	146779.	209853.	156780.	1261.
15.2	75.0	179396.	250166.	187335.	1609.
17.6	80.0	210415.	291144.	217338.	2007.
20.0	85.0	242347.	331845.	247656.	2463.
22.5	90.0	275192.	372989.	278289.	2985.
25.1	95.0	310146.	414867.	309445.	3584.
27.7	100.0	344929.	456288.	340276.	4270.
30.4	105.0	380624.	498041.	371343.	5056.
33.2	110.0	417232.	540126.	402114.	5958.
36.1	115.0	451446.	582544.	433615.	6993.
39.1	120.0	489650.	624435.	464741.	8180.
42.2	125.0	525003.	666549.	496025.	9542.
45.4	130.0	560813.	709852.	527467.	11106.
48.7	135.0	601298.	751439.	559067.	12902.
52.1	140.0	638247.	794217.	590824.	14965.
55.7	145.0	674485.	837500.	622132.	17335.
59.4	150.0	712290.	880139.	653751.	20058.
63.3	155.0	750552.	922944.	685489.	23189.
67.3	160.0	789269.	965915.	717344.	26788.
68.2	161.0	814914.	991907.	736606.	29202.

UBJECT: TANK 102 HEAT BALANCE CALCULATIONS
Y: J. SCOTT
ATE: 4-28-92

CHECKED BY: WWG
DATE: 6/2/92

PROJECT NO.: 89C114MM
TASK NO.: 5
SHEET: 19 of 32

ESULTS OF HEAT BALANCE FOR TANK 102

NPUT DATA:

VOLUME LIQUID IN TANK, GAL = 254000.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
NO INSULATION ON TANK WALL
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 10000000.

ALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

		AVG. HEAT LOSS TERMS, BTU/HR			
TIME (HR)	TEMPERATURE (F)	LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	23.	6.	4.	0.
1.0	45.0	9127.	16398.	12306.	80.
2.0	50.0	31480.	52835.	39983.	258.
3.1	55.0	57026.	91377.	68211.	460.
4.1	60.0	87818.	129863.	97425.	692.
5.2	65.0	117013.	169955.	127389.	958.
6.3	70.0	146779.	209853.	156780.	1261.
7.4	75.0	179396.	250166.	187335.	1609.
8.4	80.0	210415.	291144.	217338.	2007.
9.6	85.0	242347.	331845.	247656.	2463.
10.7	90.0	275192.	372989.	278289.	2985.
11.8	95.0	310146.	414867.	309445.	3584.
13.0	100.0	344929.	456288.	340276.	4270.
14.1	105.0	380624.	498041.	371343.	5056.
15.3	110.0	417232.	540126.	402114.	5958.
16.5	115.0	451446.	582544.	433615.	6993.
17.7	120.0	489650.	624435.	464741.	8180.
18.9	125.0	525003.	666549.	496025.	9542.
20.2	130.0	560813.	709852.	527467.	11106.
21.4	135.0	601298.	751439.	559067.	12902.
22.7	140.0	638247.	794217.	590824.	14965.
24.0	145.0	674485.	837500.	622132.	17335.
25.3	150.0	712290.	880139.	653751.	20058.
26.6	155.0	750552.	922944.	685489.	23189.
28.0	160.0	789269.	965915.	717344.	26788.
28.3	161.0	814914.	991907.	736606.	29202.

UBJECT: TANK 102 HEAT BALANCE CALCULATIONS
Y: J. SCOTT
ATE: 4-28-92
CHECKED BY: wv9
DATE: 6/2/92

PROJECT NO.: 89C114MM
TASK NO.: 5
SHEET: 20 of 32

ESULTS OF HEAT BALANCE FOR TANK 102

NPUT DATA:

VOLUME LIQUID IN TANK, GAL = 254000.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
THICKNESS OF INSULATION ON OUTER WALL BELOW LIQUID LEVEL, INCHES = 1.00
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 5000000.

ALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

		AVG. HEAT LOSS TERMS, BTU/HR			
TIME (HR)	TEMPERATURE (F)	LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	1.	6.	4.	0.
2.0	45.0	1944.	16398.	12306.	80.
4.1	50.0	5921.	52835.	39983.	258.
6.2	55.0	10066.	91377.	68211.	460.
8.4	60.0	14266.	129863.	97425.	692.
10.5	65.0	18520.	169955.	127389.	958.
12.7	70.0	22718.	209853.	156780.	1261.
15.0	75.0	27041.	250166.	187335.	1609.
17.3	80.0	31276.	291144.	217338.	2007.
19.6	85.0	35614.	331845.	247656.	2463.
21.9	90.0	39898.	372989.	278289.	2985.
24.3	95.0	44228.	414867.	309445.	3584.
26.8	100.0	48612.	456288.	340276.	4270.
29.3	105.0	52963.	498041.	371343.	5056.
31.8	110.0	57266.	540126.	402114.	5958.
34.4	115.0	61652.	582544.	433615.	6993.
37.1	120.0	66058.	624435.	464741.	8180.
39.8	125.0	70401.	666549.	496025.	9542.
42.5	130.0	74755.	709852.	527467.	11106.
45.4	135.0	79210.	751439.	559067.	12902.
48.2	140.0	83588.	794217.	590824.	14965.
51.2	145.0	87951.	837500.	622132.	17335.
54.2	150.0	92348.	880139.	653751.	20058.
57.3	155.0	96754.	922944.	685489.	23189.
60.5	160.0	101171.	965915.	717344.	26788.
61.2	161.0	103814.	991907.	736606.	29202.

UBJECT: TANK 102 HEAT BALANCE CALCULATIONS
Y: J. SCOTT
ATE: 4-28-92

CHECKED BY: WWG
DATE: 6/2/92

PROJECT NO.: 89C114MM
TASK NO.: 5
SHEET: 21 of 32

ESULTS OF HEAT BALANCE FOR TANK 102

NPUT DATA:

VOLUME LIQUID IN TANK, GAL = 254000.
INITIAL TEMPERATURE OF LIQUID IN TANK, F = 40.00
THICKNESS OF INSULATION ON OUTER WALL BELOW LIQUID LEVEL, INCHES = 1.00
AMBIENT AIR TEMPERATURE, F = 40.00
RATE OF VAPOR VENTING FROM TANK, CFM = 1100.
RATE OF HEAT ADDITION TO TANK, BTU/HR = 10000000.

ALCULATED RESULTS:

MAXIMUM POSSIBLE TEMPERATURE > 160 F

TIME (HR)	TEMPERATURE (F)	AVG. HEAT LOSS TERMS, BTU/HR LOWER WALL	UPPER WALL	ROOF	VENT
0.0	40.0	1.	6.	4.	0.
1.0	45.0	1944.	16398.	12306.	80.
2.0	50.0	5921.	52835.	39983.	258.
3.1	55.0	10066.	91377.	68211.	460.
4.1	60.0	14266.	129863.	97425.	692.
5.2	65.0	18520.	169955.	127389.	958.
6.2	70.0	22718.	209853.	156780.	1261.
7.3	75.0	27041.	250166.	187335.	1609.
8.4	80.0	31276.	291144.	217338.	2007.
9.4	85.0	35614.	331845.	247656.	2463.
10.5	90.0	39898.	372989.	278289.	2985.
11.6	95.0	44228.	414867.	309445.	3584.
12.8	100.0	48612.	456288.	340276.	4270.
13.9	105.0	52963.	498041.	371343.	5056.
15.0	110.0	57266.	540126.	402114.	5958.
16.1	115.0	61652.	582544.	433615.	6993.
17.3	120.0	66058.	624435.	464741.	8180.
18.5	125.0	70401.	666549.	496025.	9542.
19.6	130.0	74755.	709852.	527467.	11106.
20.8	135.0	79210.	751439.	559067.	12902.
22.0	140.0	83588.	794217.	590824.	14965.
23.2	145.0	87951.	837500.	622132.	17335.
24.4	150.0	92348.	880139.	653751.	20058.
25.6	155.0	96754.	922944.	685489.	23189.
26.9	160.0	101171.	965915.	717344.	26788.
27.1	161.0	103814.	991907.	736606.	29202.

Subject Tank 102 Heat Transfer Calculations
By J. Scott　　Checked by WWG
Date 4-28-92　　Date 6/2/92

Project No. 89C114MM
Task No. 5
Sheet 22 of 32

```
C
C     HEAT BALANCE CALCULATIONS FOR TANK 102
C
C     CFM = RATE OF REMOVAL OF GAS FROM TANK THROUGH VENT, CFM
C     HCAP = HEAT CAPACITY OF LIQUID IN TANK, BTU/LB/F
C     QCONV = TOTAL CONVECTIVE LOSS THRU WALL AND ROOF, BTU/HR
C     QIN = HEAT ADDED TO TANK, BTU/HR
C     QRAD = TOTAL RADIATION LOSS THRU WALL AND ROOF, BTU/HR
C     QVAP = TOTAL HEAT REMOVED FROM VAPOR VENTING, BTU/HR
C     RHOL = DENSITY OF LIQUID IN TANK, LB/GAL
C     T = TEMPERATURE OF LIQUID IN TANK, F
C     TO = INITIAL TEMPERATURE OF LIQUID IN TANK, F
C     TAIR = TEMPERATURE OF AMBIENT AIR, F
C     TIME = ELAPSED TIME SINCE START OF HEATING, HR
C     TMAX = MAXIMUM POSSIBLE TEMPERATURE OF LIQUID IN TANK, F
C     VOL = VOLUME OF LIQUID IN TANK, GAL
C     WINS = THICKNESS OF INSULATION ON TANK OUTER WALL BELOW
LIQUID LEVEL, INCHES
C
C
      REAL*4 HCAP,QLOW,QHI,QROOF,QVAP,QIN,WINS
      REAL*4 RHOL,T,TO,TAIR,TIME,TMAX,VOL,CFM
      REAL*4 TT(3),QQ(3)
      DATA HCAP/0.8/
      DATA RHOL/10.0/
C
C     READ IN DATA FOR RUN
C
      WRITE(*,100)
100   FORMAT(1X,'HEAT BALANCE CALCULATIONS FOR TANK 102')
      WRITE(*,110)
110   FORMAT(1X,'INPUT VOLUME OF LIQUID IN TANK, GAL')
      WRITE(*,120)
120   FORMAT(1X,'>')
      READ(*,*) VOL
      WRITE(*,130)
130   FORMAT(1X,'INPUT INITIAL TEMPERATURE OF LIQUID IN TANK, F')
      WRITE(*,120)
      READ(*,*) TO
      WRITE(*,140)
140   FORMAT(1X,'INPUT THICKNESS OF INSULATION ON TANK WALL
BELOW',/,
     11X,'LIQUID LEVEL, INCHES')
```

```
      WRITE(*,120)
      READ(*,*) WINS
      WRITE(*,150)
150   FORMAT(1X,'INPUT AMBIENT AIR TEMPERATURE, F')
      WRITE(*,120)
      READ(*,*) TAIR
      WRITE(*,160)
160   FORMAT(1X,'INPUT RATE OF GAS VENTING FROM TANK, CFM')
      WRITE(*,120)
      READ(*,*) CFM
      WRITE(*,170)
170   FORMAT(1X,'INPUT RATE OF HEAT INPUT TO TANK, BTU/HR')
      WRITE(*,120)
      READ(*,*) QIN
C
C     COMPUTE MAXIMIM POSSIBLE TEMPERATURE IN TANK
C
      TT(1)=TAIR+.01
      TT(2)=160.
      QQ(1)=0.0
      QQ(2)=0.0
      QQ(3)=0.0
C
C     USE BISECTION METHOD TO SOLVE EQUATIONS FOR HEAT TRANSFER
SO THAT
C     RATE OF HEAT INPUT IS EQUAL TO RATE OF HEAT LOSS THROUGH
TANK WALL,
C     TANK COVER, AND GAS VENTED AT TANK LIQUID TEMPERATURE
EQUAL TO
C     MAXIMUM POSSIBLE TEMPERATURE
C
      CALL WALLOW(QLOW,VOL,WINS,TT(1),TAIR)
      CALL WALHI(QHI,VOL,TT(1),TAIR)
      CALL ROOF(QROOF,TT(1),TAIR)
      CALL VAPOR(QVAP,TT(1),TAIR,CFM)
      QQ(1)=QIN-(QLOW+QHI+QROOF+QVAP)
      IF(QQ(1).LE.0.0) GO TO 230
      CALL WALLOW(QLOW,VOL,WINS,TT(2),TAIR)
      CALL WALHI(QHI,VOL,TT(2),TAIR)
      CALL ROOF(QROOF,TT(2),TAIR)
      CALL VAPOR(QVAP,TT(2),TAIR,CFM)
      QQ(2)=QIN-(QLOW+QHI+QROOF+QVAP)
      IF(QQ(2).GT.0.0) GO TO 250
```

Subject Tank 102 Heat Transfer Calculations — Project No. 89C114MM
By J. Scott — Checked by JWS — Task No. 5
Date 4-28-92 — Date 6/2/92 — Sheet 24 of 32

```
200  TT(3)=(TT(1)+TT(2))/2.
     CALL WALLOW(QLOW,VOL,WINS,TT(3),TAIR)
     CALL WALHI(QHI,VOL,TT(3),TAIR)
     CALL ROOF(QROOF,TT(3),TAIR)
     CALL VAPOR(QVAP,TT(3),TAIR,CFM)
     QQ(3)=QIN-(QLOW+QHI+QROOF+QVAP)
     IF(ABS(QQ(3)).LT.100) GO TO 220
     IF(QQ(3).LT.0.0) GO TO 210
     TT(1)=TT(3)
     QQ(1)=QQ(3)
     GO TO 200
210  TT(2)=TT(3)
     QQ(2)=QQ(3)
     GO TO 200
220  TMAX=TT(3)
     GO TO 270
230  WRITE(*,240)
240  FORMAT(1X,'MAXIMUM TEMPERATURE POSSIBLE IS LESS THAN',
    1/,1X,'AMBIENT AIR TEMPERATURE. RUN STOPPED')
     GO TO 600
250  TMAX=161.0
     WRITE(*,260)
260  FORMAT(1X,'MAXIMUM TEMPERATURE POSSIBLE IS GREATER THAN',
    1/,1X,'160 F')
270  CONTINUE
C
C    COMPUTE RATE OF TEMPERATURE INCREASE IN TANK 102
C
C    PRINT HEADINGS FOR OUTPUT
C
     OPEN(UNIT=6,FILE='LPT1')
     WRITE(6,300)
300  FORMAT(1X,'SUBJECT: TANK 102 HEAT BALANCE CALCULATIONS',7X,
    1'PROJECT NO.: 89C114MM')
     WRITE(6,310)
310  FORMAT(1X,'BY: J. SCOTT',8X,'CHECKED BY:',19X,'TASK NO.: 5')
     WRITE(6,320)
320  FORMAT(1X,'DATE: 4-28-92',7X,'DATE:',25X,'SHEET:',/)
     WRITE(6,325)
325  FORMAT(1X,72('-'),/)
     WRITE(6,330)
330  FORMAT(1X,'RESULTS OF HEAT BALANCE FOR TANK 102',/)
     WRITE(6,340)
```

Subject Tank 102 Heat Transfer Calculations
By J. Scott   Checked by 2/2/9
Date 4-28-92   Date 6/2/92

Project No. 89C114MM
Task No. 5
Sheet 25 of 32

```
340  FORMAT(1X,'INPUT DATA:',/)
     WRITE(6,350) VOL
350  FORMAT(1X,5X,'VOLUME LIQUID IN TANK, GAL = ',F8.0)
     WRITE(6,360) TO
360  FORMAT(1X,5X,'INITIAL TEMPERATURE OF LIQUID IN TANK, F = ',F8.2)
     IF(WINS.LE.0.0) WRITE(6,370)
370  FORMAT(1X,5X,'NO INSULATION ON TANK WALL')
     IF(WINS.GT.0.0) WRITE(6,380) WINS
380  FORMAT(1X,5X,'THICKNESS OF INSULATION ON OUTER WALL BELOW
LIQUID
    1LEVEL, INCHES = ',F5.2)
     WRITE(6,390) TAIR
390  FORMAT(1X,5X,'AMBIENT AIR TEMPERATURE, F = ',F8.2)
     WRITE(6,400) CFM
400  FORMAT(1X,5X,'RATE OF VAPOR VENTING FROM TANK, CFM = ',F8.0)
     WRITE(6,410) QIN
410  FORMAT(1X,5X,'RATE OF HEAT ADDITION TO TANK, BTU/HR = ',F10.0)
     WRITE(6,420)
420  FORMAT(1X,//,1X,'CALCULATED RESULTS:',/)
     IF(TMAX.LE.160.0) WRITE(6,430) TMAX
430  FORMAT(1X,5X,'MAXIMUM POSSIBLE TANK TEMPERATURE, F = ',F8.2,/)
     IF(TMAX.GT.160.0) WRITE(6,440)
440  FORMAT(1X,5X,'MAXIMUM POSSIBLE TEMPERATURE > 160 F',//)
     WRITE(6,450)
450  FORMAT(1X,26X,'AVG. HEAT LOSS TERMS, BTU/HR')
     WRITE(6,460)
460  FORMAT(1X,2X,'TIME',4X,'TEMPERATURE',2X,'LOWER WALL',2X,
    1'UPPER WALL',5X,'ROOF',8X,'VENT')
     WRITE(6,470)
470  FORMAT(1X,2X,'(HR)',8X,'(F)',/)
C
C      STEP UP LIQUID TEMPERATURE IN 5 F INCREMENTS.  USE HEAT
BALANCE EQUATION
C   TO SOLVE FOR TIME REQUIRED TO HEAT VOLUME OF LIQUID 5 F.  THE
RATE OF
C        AT WHICH THE TANK CAN BE HEATED IS CALCULATED BY
SUBTRACTING THE HEAT LOSS
C   TERMS THROUGH TANK WALL, TANK COVER, AND GAS VENTED FROM
CONSTANT HEAT
C   INPUT TO ARRIVE AT NET ENERGY AVAILABLE FOR HEATING LIQUID.
THE HEAT LOSS
C        TERMS ARE AVERAGE VALUES CALCULATED FOR A LIQUID
TEMPERATURE HALF WAY IN
```

Subject Tank 102 Heat Transfer Calculations
By J. Scott
Date 4-28-92
Checked by 7/29
Date 6/2/92
Project No. 89C114MM
Task No. 5


```
C      BETWEEN THE PREVIOUS LIQUID TEMPERATURE AND THE NEW
TEMPERATURE INCREASED
C    BY 5 F
C
      TIME=0.0
      T=TO
      CALL WALLOW(QLOW,VOL,WINS,T,TAIR)
      CALL WALHI(QHI,VOL,T,TAIR)
      CALL ROOF(QROOF,T,TAIR)
      CALL VAPOR(QVAP,T,TAIR,CFM)
      WRITE(6,500) TIME,T,QLOW,QHI,QROOF,QVAP
500   FORMAT(1X,F8.1,4X,F7.1,4X,F10.0,2X,F10.0,2X,F10.0,2X,F10.0)
510   TT(2)=T+5.0
      IF(TT(2).GE.TMAX) GO TO 520
      TT(1)=T+2.5
      CALL WALLOW(QLOW,VOL,WINS,TT(1),TAIR)
      CALL WALHI(QHI,VOL,TT(1),TAIR)
      CALL ROOF(QROOF,TT(1),TAIR)
      CALL VAPOR(QVAP,TT(1),TAIR,CFM)
      QQ(1)=QIN-(QLOW+QHI+QROOF+QVAP)
      TIME=TIME+5.0*RHOL*VOL*HCAP/QQ(1)
      T=TT(2)
      WRITE(6,500) TIME,T,QLOW,QHI,QROOF,QVAP
      GO TO 510
520   TT(1)=(T+TMAX)/2.0
      TT(2)=TMAX
      CALL WALLOW(QLOW,VOL,WINS,TT(1),TAIR)
      CALL WALHI(QHI,VOL,TT(1),TAIR)
      CALL ROOF(QROOF,TT(1),TAIR)
      CALL VAPOR(QVAP,TT(1),TAIR,CFM)
      QQ(1)=QIN-(QLOW+QHI+QROOF+QVAP)
      TIME=TIME+(TMAX-T)*RHOL*VOL*HCAP/QQ(1)
      T=TT(2)
      WRITE(6,500) TIME,T,QLOW,QHI,QROOF,QVAP
600   CONTINUE
      CLOSE(6)
      END
C
C ***********************************************
C
      SUBROUTINE WALLOW(QLOW,VOL,WINS,TLIQ,TAIR)
C
C     CALCULATE HEAT LOSS THRU TANK WALL BELOW LIQUID LEVEL
```

Subject Tank 102 Heat Transfer Calculations
By J. Scott
Date 4-28-92
Checked by VWG
Date 6/2/92

Project No. 89C114MM
Task No. 5
Sheet 27 of 32

```
C
C    AWALL = SURFACE AREA OF TANK WALL BELOW LIQUID LEVEL, SQ FT
C    CWALL = CONSTANT IN EQUATION FOR CONVECTIVE HEAT TRANSFER
COEFFICIENT
C      EPS = EMISSION CONSTANT IN EQUATION FOR RADIATION HEAT
TRANSFER COEFFICIENT
C    HCOND = CONDUCTIVE HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ
FT
C    HCONV = CONVECTIVE HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ
FT
C    HRAD = RADIATION HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ FT
C    KHDPE = THERMAL CONDUCTIVITY OF HDPE LINER, BTU*IN/HR/F/SQ
FT
C    KINS = THERMAL CONDUCTIVITY OF INSULATION, BTU*IN/HR/F/SQ FT
C    QLOW = TOTAL HEAT LOSS THRU WALL BELOW LIQUID LEVEL, BTU/HR
C    TAIR = TEMPERATURE OF AMBIENT AIR, F
C    TLIQ = TEMPERATURE OF TANK LIQUID, F
C    TW = TEMPERATURE OF OUTER SKIN OF TANK WALL, F
C    VOL = VOLUME OF LIQUID IN TANK, GAL
C    WIND = AMBIENT WIND VELOCITY, MPH
C    WHDPE = LINER THICKNESS, INCHES
C    WINS = INSULATION THICKNESS, INCHES
C
      REAL*4 QLOW,TLIQ,TAIR,AWALL,WIND,CWALL
      REAL*4 HCOND,KHDPE,KINS,WHDPE,WINS
      REAL*4 EPS,HCONV,HRAD,VOL,TW
      REAL*4 Q(3),T(3)
      DATA CWALL/1.394/
      DATA WIND/7.5/
      DATA EPS/0.8/
      DATA KINS/0.6/
      DATA KHDPE/2.7/
      DATA WHDPE/0.1/
      DO 10 I=1,3
      Q(I)=0.0
      T(I)=0.0
10    CONTINUE
      T(1)=TLIQ
      T(3)=TAIR
      IF(WINS.LE.0.0) GO TO 20
      HCOND=1.0/(1.0/(KHDPE/WHDPE)+1.0/(KINS/WINS))
      GO TO 30
20    HCOND=KHDPE/WHDPE
```

```
30  HCONV=CWALL*(1./24)**.2*(2./(T(1)+TAIR))**.181*(T(1)-TAIR)**.266
    HCONV=HCONV*SQRT(1.+1.277*WIND)
    HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(1)+459.6)**4)/(TAIR-T(1))
    Q(1)=HCOND*(TLIQ-T(1))-(HCONV+HRAD)*(T(1)-TAIR)
    HCONV=CWALL*(1./24)**.2*(2./(T(3)+TAIR))**.181*(T(3)-TAIR)**.266
    HCONV=HCONV*SQRT(1.+1.277*WIND)
    HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(3)+459.6)**4)/(TAIR-T(3))
    Q(3)=HCOND*(TLIQ-T(3))-(HCONV+HRAD)*(T(3)-TAIR)
40  T(2)=(T(1)+T(3))/2.0
    IF(ABS(T(1)-T(2)).LE.0.05)  GO TO 100
    HCONV=CWALL*(1./24)**.2*(2./(T(2)+TAIR))**.181*(T(2)-TAIR)**.266
    HCONV=HCONV*SQRT(1.+1.277*WIND)
    HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(2)+459.6)**4)/(TAIR-T(2))
    Q(2)=HCOND*(TLIQ-T(2))-(HCONV+HRAD)*(T(2)-TAIR)
    IF(Q(1)*Q(2).GE.0.0) GO TO 50
    T(3)=T(2)
    GO TO 40
50  T(1)=T(2)
    GO TO 40
100 TW=T(2)
    AWALL=4.0*VOL/(78.5*7.481)
    QLOW=HCOND*(TLIQ-TW)*AWALL
    RETURN
    END
C
C ********************************************
C
    SUBROUTINE WALHI(QHI,VOL,TLIQ,TAIR)
C
C   CALCULATE HEAT LOSS THRU TANK WALL ABOVE LIQUID LEVEL
C
C   AWALL = SURFACE AREA OF TANK WALL ABOVE LIQUID LEVEL, SQ FT
C   CWALL = CONSTANT IN EQUATION FOR CONVECTIVE HEAT TRANSFER
COEFFICIENT
C   EPS = EMISSION CONSTANT IN EQUATION FOR RADIATION HEAT
TRANSFER COEFFICIENT
C   HCOND = CONDUCTIVE HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ
FT
C   HCONV = CONVECTIVE HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ
FT
C   HFILM = HEAT TRANSFER COEFFICIENT AIR FILM INSIDE TANK,
BTU/HR/F/SQ FT
C   HRAD = RADIATION HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ FT
```

Subject Tank 102 Heat Transfer Calculations
By J. Scott
Date 4-28-92
Checked by DWG
Date 6/2/92
Project No. 89C114MM
Task No. 5


```
C    KHDPE = THERMAL CONDUCTIVITY OF HDPE LINER, BTU*IN/HR/F/SQ
FT
C    QHI = TOTAL HEAT LOSS THRU WALL ABOVE LIQUID LEVEL, BTU/HR
C    TAIR = TEMPERATURE OF AMBIENT AIR, F
C    TLIQ = TEMPERATURE OF TANK LIQUID, F
C    TW = TEMPERATURE OF OUTER SKIN OF TANK WALL, F
C    VOL = VOLUME OF LIQUID IN TANK, GAL
C    WHDPE = LINER THICKNESS, INCHES
C    WIND = AMBIENT WIND VELOCITY, MPH
C
      REAL*4 QHI,TLIQ,TAIR,AWALL,WIND,CWALL
      REAL*4 HCOND,TW,HFILM,KHDPE,WHDPE
      REAL*4 EPS,HCONV,HRAD,VOL
      REAL*4 Q(3),T(3)
      DATA CWALL/1.394/
      DATA WIND/7.5/
      DATA EPS/0.8/
      DATA HFILM/1.47/
      DATA KHDPE/2.7/
      DATA WHDPE/0.1/
      DO 10 I=1,3
      Q(I)=0.0
      T(I)=0.0
10    CONTINUE
      HCOND=1.0/(1.0/HFILM+WHDPE/KHDPE)
      T(1)=TLIQ
      T(3)=TAIR
      HCONV=CWALL*(1./24)**.2*(2./(T(1)+TAIR))**.181*(T(1)-TAIR)**.266
      HCONV=HCONV*SQRT(1.+1.277*WIND)
      HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(1)+459.6)**4)/(TAIR-T(1))
      Q(1)=HCOND*(TLIQ-T(1))-(HCONV+HRAD)*(T(1)-TAIR)
      HCONV=CWALL*(1./24)**.2*(2./(T(3)+TAIR))**.181*(T(3)-TAIR)**.266
      HCONV=HCONV*SQRT(1.+1.277*WIND)
      HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(3)+459.6)**4)/(TAIR-T(3))
      Q(3)=HCOND*(TLIQ-T(3))-(HCONV+HRAD)*(T(3)-TAIR)
40    T(2)=(T(1)+T(3))/2.0
      IF(ABS(T(1)-T(2)).LE.0.05)  GO TO 100
      HCONV=CWALL*(1./24)**.2*(2./(T(2)+TAIR))**.181*(T(2)-TAIR)**.266
      HCONV=HCONV*SQRT(1.+1.277*WIND)
      HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(2)+459.6)**4)/(TAIR-T(2))
      Q(2)=HCOND*(TLIQ-T(2))-(HCONV+HRAD)*(T(2)-TAIR)
      IF(Q(1)*Q(2).GE.0.0) GO TO 50
      T(3)=T(2)
```

```
      GO TO 40
50    T(1)=T(2)
      GO TO 40
100   TW=T(2)
      AWALL=9865-4.0*VOL/(78.5*7.481)
      QHI=HCOND*(TLIQ-TW)*AWALL
      RETURN
      END
C
C  **********************************************
C
      SUBROUTINE ROOF(QROOF,TLIQ,TAIR)
C
C     CALCULATE HEAT LOSS THRU TANK ROOF
C
C     AROOF = SURFACE AREA OF TANK ROOF, SQ FT
C     CROOF = CONSTANT IN EQUATION FOR CONVECTIVE HEAT TRANSFER
COEFFICIENT
C     EPS = EMISSION CONSTANT IN EQUATION FOR RADIATION HEAT
TRANSFER COEFFICIENT
C     HCONV = CONVECTIVE HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ
FT
C     HFILM = HEAT TRANSFER COEFFICIENT FOR AIR FILM ON INSIDE OF
TANK, BTU/HR/SQ FT/F
C     HRAD = RADIATION HEAT TRANSFER COEFFICIENT, BTU/HR/F/SQ FT
C     QROOF = TOTAL HEAT LOSS THRU TANK ROOF, BTU/HR
C     TAIR = TEMPERATURE OF AMBIENT AIR, F
C     TLIQ = TEMPERATURE OF TANK LIQUID, F
C     TW = TEMPERATURE OF OUTER SKIN OF TANK ROOF, F
C     WIND = AMBIENT WIND VELOCITY, MPH
C
      REAL*4 QROOF,TLIQ,TAIR,AROOF,WIND,CROOF
      REAL*4 HFILM,TW
      REAL*4 EPS,HCONV,HRAD
      REAL*4 Q(3),T(3)
      DATA CROOF/1.61/
      DATA AROOF/6211/
      DATA WIND/7.5/
      DATA EPS/0.8/
      DATA HFILM/1.3/
      DO 10 I=1,3
      Q(I)=0.0
      T(I)=0.0
```

Subject Tank 102 Heat Transfer Calculations
By J. Scott
Date 4-28-92
Checked by WWS
Date 6/2/92

Project No. 89C114MM
Task No. 5
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```
10   CONTINUE
     T(1)=TLIQ
     T(3)=TAIR
     HCONV=CROOF*(1./24)**.2*(2./(T(1)+TAIR))**.181*(T(1)-TAIR)**.266
     HCONV=HCONV*SQRT(1.+1.277*WIND)
     HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(1)+459.6)**4)/(TAIR-T(1))
     Q(1)=HFILM*(TLIQ-T(1))-(HCONV+HRAD)*(T(1)-TAIR)
     HCONV=CROOF*(1./24)**.2*(2./(T(3)+TAIR))**.181*(T(3)-TAIR)**.266
     HCONV=HCONV*SQRT(1.+1.277*WIND)
     HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(3)+459.6)**4)/(TAIR-T(3))
     Q(3)=HFILM*(TLIQ-T(3))-(HCONV+HRAD)*(T(3)-TAIR)
40   T(2)=(T(1)+T(3))/2.0
     IF(ABS(T(1)-T(2)).LE.0.05)  GO TO 100
     HCONV=CROOF*(1./24)**.2*(2./(T(2)+TAIR))**.181*(T(2)-TAIR)**.266
     HCONV=HCONV*SQRT(1.+1.277*WIND)
     HRAD=0.1713E-8*EPS*((TAIR+459.6)**4-(T(2)+459.6)**4)/(TAIR-T(2))
     Q(2)=HFILM*(TLIQ-T(2))-(HCONV+HRAD)*(T(2)-TAIR)
     IF(Q(1)*Q(2).GE.0.0) GO TO 50
     T(3)=T(2)
     GO TO 40
50   T(1)=T(2)
     GO TO 40
100  TW=T(2)
     QROOF=HFILM*(TLIQ-TW)*AROOF
     RETURN
     END
C
C ***********************************************
C
     SUBROUTINE VAPOR(QVAP,T,TAIR,CFM)
C
C    CALCULATE HEAT LOSS FROM GAS VENTED FROM TANK
C
C    CFM = RATE OF VAPOR VENTING FROM TANK, CFM
C    QVAP = TOTAL HEAT REMOVED FROM VAPOR VENTING, BTU/HR
C    T = TEMPERATURE OF LIQUID IN TANK, F
C    TAIR = TEMPERATURE OF AMBIENT AIR, F
C
     REAL*4 QVAP,T,TAIR,RHOAIR,HAIR,CFM
     REAL*4 H
     REAL*4 CRHO(3),CH(3)
     DATA CRHO/.0655243556,6.53147E-6,-1.19101E-6/
     DATA CH/1.7742856887,.0259026855,.0000053392/
```

```
RHOAIR=CRHO(1)+TAIR*CRHO(2)+TAIR*TAIR*CRHO(3)
HAIR=EXP(CH(1)+CH(2)*TAIR+CH(3)*TAIR*TAIR)
H=EXP(CH(1)+CH(2)*T+CH(3)*T*T)
QVAP=CFM*RHOAIR*(H-HAIR)
RETURN
END
```

Subject: Volume Liquid in Tank During Crystal Dissolution | Project No. 89C114MM

By: J. Scott | Checked By: WWG | Task No. 5

Date: 4/27/92 | Date: 4/27/92 | File No.

Sheet 1 of 2

Calculate volume of liquid in Tank 102 during crystal dissolution for use in liquid heating design calculations

Tank conditions prior to dissolution

Tank diameter = 78.5'

Height of liquid = ?

6" - nozzle for removal of Basin F liquid to SQI is located 4'-0" above tank bottom. Assume liquid removed to within 1" above top elevation of removal nozzle

Height of liquid = 4'-0" + 3" + 1" = 4'-4"

Data from Alternatives Assessment Report

Depth of crystals in Tank 102 bottom = 2.6'

Volume of liquid resulting from each yd^3 crystals dissolved for case where crystal void space filled with Basin F liquid is 410 gallon/yd^3

Volume of water required to dissolve crystals = 230 gallon/yd^3

Volume of liquid from crystal dissolution:

Volume crystals $2.6' \times \pi/4 \times (78.5')^2 \times 1\ yd^3/27\ ft^3$
$= 466\ yd^3$

Required volume of water $466\ yd^3 \times 230\ gal/yd^3$
$= 107,193\ gal$

Resulting volume from crystal dissolution $466\ yd^3 \times 410\ gal/yd^3$
$= 191,060\ gal$

Subject: Volume Liquid in Tank During Crystal Dissolution
Project No. 89 C 114MM
Task No. 5
By J. Scott
Checked By WWG
File No.
Date 4/27/92
Date 4/27/92
Sheet 2 of 2

Volume of Basin F liquid above crystal layer:

4'-4" = 4.33'

(4.33' - 2.6') = 1.73' Basin F liquid

$1.73' \times \pi/4 \times (78.5')^2 \times 7.481\ gal/ft^3 = 62,638\ gal$

Total volume liquid in tank after crystal dissolution

191,060 + 62,638 = 253,700 gallons

From alternatives assessment fluid specific gravity = 1.2

$253,700\ gal \times 8.33\ lb/gal \times 1.2 = 2.54 \times 10^6\ lbs$ liquid

Final height of fluid in tank:

$253,700\ gal \times 1\ ft^3/7.481\ gal = 33,913\ ft^3$

$33,913\ ft^3 = h \times \pi/4 \times (78.5')^2$

$h = 7.01'$

MECHANICAL DESIGN CALCULATIONS FOR EMISSION CONTROL SYSTEM

Subject: Emission Control System Equipment Selection
Project No. 89C114MM
Task No. 5
By J. Scott
Checked By WWG
File No.
Date 5/28/92
Date 6/2/9
Sheet 1 of 4

Emission control system consists of two separate trains, one to treat low volume of gas vented from Tank 102 during Phase One - Crystal Dissolution and one to treat high volume of gas vented from tank 102 when access port is added for tank interior decontamination. Each train will consist in series downstream of Tank 102 an ammonia scrubber (including packed tower, scrubber liquid circulation pump, acid feed pump, and associated piping, instruments, and controls), an air blower, and a GAC air filter.

1) Low volume system.

Design basis vent 1400 cfm at 140 °F, 100% humidity.

Ammonia 1.4 mg/l Total Organics 0.0001 mg/l

D-102 Ammonia Scrubber: Design obtained from vendor, Ceilcote/Air Pollution Control. Design for 99% removal of ammonia under above inlet conditions.

Model SPT-24-72 24" ϕ x 72" packing
Liquid circulation rate (pH 2-4), 19 gpm
air pressure drop = 2" H_2O
Size pump for 60' TDH

P-104
P-105
20 gpm pump at 60' TDH to circulate scrubber liquid. Fluid 5% TDS (ammonium sulfate) and pH 2. Pump recommendation from vendor, Goulds Pumps.

Model 3196 STX End suction centrifugal ANSI pump, 316 SS construction for chemical compatibility (pump this size SS construction near same cost as steel). Double mechanical seal, 3-hp, 3ϕ, 460V, TEFC Motor

Efficiency is very low.

Woodward-Clyde Consultants

Subject: Emission Control System Equipment Selection
Project No. 89C114MM
By J. Scott
Checked By [illegible]
Task No. 5
File No.
Date 5/28/92
Date 6/2/92
Sheet 2 of 4

P-107 Chemical feed pump to add make-up 50% sulfuric acid to scrubber liquid to maintain pH 2. Require 0.061 gpm acid (from mass balance calculations) = 3.7 gph. Want metering pump to deliver controlled amount of acid based on signal from pH controller. Make design output of pump mid-range of actual pump. Manual stroke length control. Automatic stroke frequency control. Minimum 20 psig delivery pressure. Typical manufacturer, LMI electronic metering pumps.

Model B43 series 0-4.5 gph output, 50 psi injection pressure. Motor in NEMA 4 enclosure.

F-102 GAC filter unit(s) to treat vented air for removal of organics/odors. Flow of ~1200 cfm at 60°F to be treated.

Objective to use standard rental unit available from manufacturer who is able to regenerate waste GAC with Basin F RCRA codes.

Vendor information received from Calgon Carbon Corporation was reviewed and the Vapor Pac Service Units rental units were selected as best choice. Two units would be required with flow through each unit of 600 cfm.

S.S. construction 5' Ø x 7' 3" ht.
1800 lb. 6x16 BPL GAC = 60 ft³
ΔP = 7 inches H_2O at 600 cfm

BL-102 To vent 1200 cfm air from Tank 102 through ammonia scrubber and GAC filter units. Total pressure loss through system including duct ≈ 1" + 2" + 7" = 10" H_2O

Woodward-Clyde Consultants

Subject Emission Control System Equipment Se[illegible]

By J. Scott

Checked By WWG

Date 5/28/92

Date 6/2/92

Project No. 89C114 MM

Task No. 5

File No.

Sheet 3 of 4

Design obtained from vendor, New York Blower Company.

Industrial centrifugal fan 1100 cfm at 12" SP. Belt driven with 7.5 hp, 3 Φ, 460V TEFC motor

2) High Volume System

Design basis vent 13,000 cfm at 40 °F.

Ammonia 0.14 mg/l Total Organics 0.00001 mg/l

D-101 Ammonia scrubber. Design obtained from vendor, Ceilcote / Air Pollution Control. Design for 99% ammonia removal.

Model SPT-72-72 72" Φ x 72" packing
Liquid circulation rate (pH 2-4) 170 gpm
air pressure drop = 2" H_2O
size pump for 60' TDH

P-103 170 gpm at 60' TDH to circulate scrubber liquid. Fluid 5% TDS and pH 2. Pump reccomendation from vendor, Goulds Pumps.

Model 3196STX end suction centrifugal ANSI pump. 316 SS construction (pump this size SS construction near same cost as steel). Double mechanical seal. 5 hp, 3 Φ, 460V TEFC motor

P-106 Chemical feed pump to add make-up 50% sulfuric acid to maintain pH 2. Require 0.057 gpm acid (from mass balance calculation) = 3.4 gph

Use same pump as for P-107

Woodward-Clyde Consultants

Subject Emission Control System Equipment ... Project No. 89C114MM
Task No. 5
By J. Scott Checked By WWG File No.
Date 5/28/92 Date 6/2/92 Sheet 4 of 4

F-101 GAC filter unit to treat vented air for removal of organics/odors. Flow of 13,000 cfm at 40 °F to be treated.

Vendor information from Calgon Carbon Corporation reviewed and the Vapor-Pac 10 Service rental units were selected as best choice. Two units would be required with flow through each unit of 6500 cfm

Epoxy steel construction 22'-4" length × 8'-0" width × 8'-4" height
12,500 lbs 4×10 BPL GAC
ΔP = 6 inches H_2O at 6500 cfm

BL-101 To vent 13,000 cfm air flow from Tank 102 through ammonia scrubber and GAC filter units. Total pressure loss through system including duct ≈ 3" + 2" + 6" = 11" H_2O

Design obtained from vendor, New York Blower Company

Industrial centrifugal fan 13,000 cfm at 12" H_2O SP. Belt driven with 40 hp, 3φ, 460V TEFC motor.

Subject Tank 102 Vent Gas Treatment NH3 Scrubber Project No. 89C114MM

By J. Scott Checked By ESR Task No. 5

File No.

Date 4-30-92 Date 5/27/92 Sheet 1 of 2

Assumptions for design of ammonia scrubbers:

Will be two scrubber systems required

1) for venting of closed tank during operation of liquid heating and circulation system during crystal dissolution phase.

2) for purging of tank after access hole cut into side for entry during tank interior decontamination phase.

1) calculations for rate of leakage of air into tank through seams in aluminum cover when maintained at -0.1 inch water.

1100 cfm at avg temperature of assumed of 40 °F

Assume that this air will come to equilibrium with tank liquid at 140 °F before removal through scrubber. (worst case)

So air into scrubber will be 1400 cfm at 140 °F and 100 % humidity

From off-gas studies conducted by WES in Alternatives Assessment Report during crystal dissolving at 140 °F in water or Basin F liquid/water mixture

Based laboratory method of trapping ammonia in acid and analyzing amount collected

$NH_3 \simeq 1.4$ mg/l

Based on Drager tube readings

$NH_3 \simeq 1-25$ mg/l

However, subsequent conversation with

Subject Tank 102 Vent Gas Treatment NH_3 Scrubber Project No. 89C114MM

By J. Scott Checked By ESR Task No. 5

File No.

Date 4-30-92 Date 5/27/92 Sheet 2 of 2

Beth Fleming at WES revealed that reported units of Draeger tubes should have been ppm (volume) not mg/l.

25 ppm NH_3 $\simeq$ 0.017 mg/l NH_3

No explanation for descrepancy. However, laboratory analysis is likely more reliable and will represent most conservative assumption!

Assume NH_3 in vent gas = 1.4 mg/l

2) Calculations for rate of air purge into tank to maintain velocity of 200 fpm through 8' x 8' access hold 13,000 cfm

Tank will be at ambient temperature conditions and so air flow into scrubber

13,000 cfm at 40 °F, 60 % humidity

Air flow through tank is 10 x that of case 1 and temperature is ambient.

Conservative assumption for ammonia concentration is

NH_3 in vent gas = 0.14 mg/l

3) Small Ammonia Scrubber

Entering air will be at 140 °F, 100% humidity

Ambient temperature 40 °F

Assume scrubber liquid steady state temperature is 60 °F

Woodward-Clyde Consultants

Subject Tank 102 Vent Gas Treatment NH_3 Scrubber

By J. Scott

Date 4-30-92

Checked By E.S. Reilly

Date 5/27/92

Project No. 89C114MM

Task No. 5

File No.

Estimation of acid use and blowdown rate for ammonia scrubber design.

Design basis Assumptions:

Scrubber #1

Inlet gas 1,400 cfm, 100 % humidity, 140 °F, 1.4 mg/l NH_3

Scrubber #2

Inlet gas 13,000 cfm 60 % humidity, 40 °F, assume 0.14 mg/l ammonia

Neutralization reaction using sulfuric acid to maintain scrubber water pH 2-4

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

$pH = 2 \Rightarrow [H^+] = 0.01$ mole/l or

0.005 mole/l H_2SO_4

1 mole H_2SO_4 required per 2 moles NH_3 adsorbed

To estimate Make-up acid use = stoichmetric requirement + loss through blowdown

(Vendor recommendation)

To estimate blow down maintain total dissolved solids < 5 weight % (Vendor recommendation)

Make-up water to replace blowdown and evaporation loss

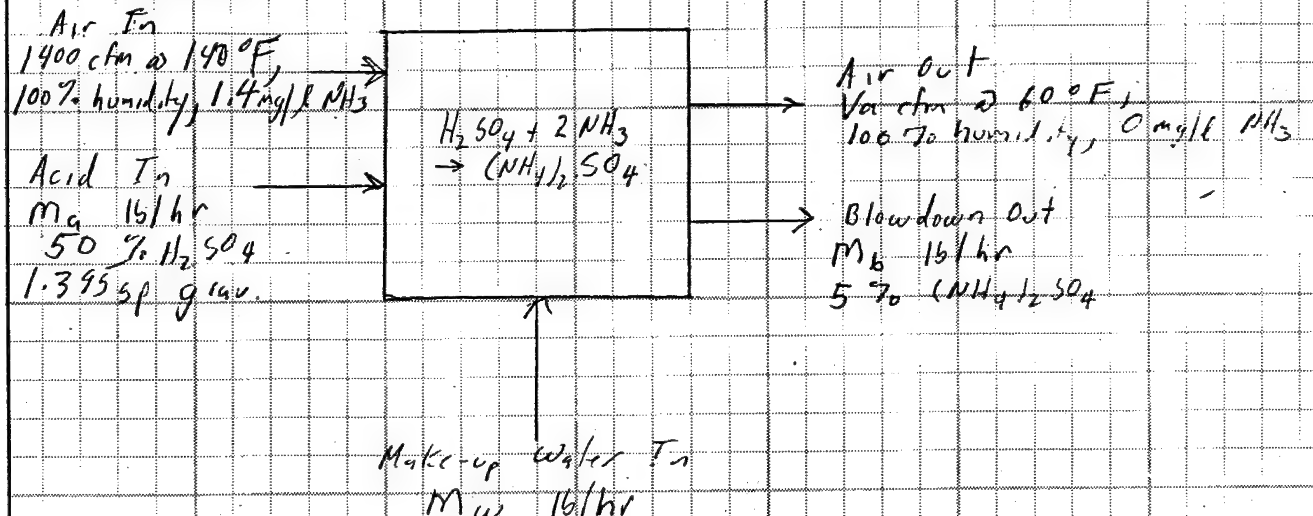
Subject Task 102 Vent Gas Treatment NH_3 Scrubber | Project No. 89C114MM

Task No. 5

By J. Scott | Checked By ESR | File No.

Date 4-30-92 | Date 5/27/92 | Sheet 2 of 6

Scrubber #1



Air In

Air at 140 °F, 100 % humidity, 24.6 in Hg — Perry's Tables 12-1, 12-2

$H = 0.1534 + 0.0429 = 0.1963$ lb H_2O/lb dry air ✓

$V = 24.25$ ft^3/lb dry air ✓ (equation on Table 12-2)

1400 ft^3/min / 24.25 ft^3/lb dry air = 57.73 lb dry air/min ✓

0.1963 lb H_2O/lb dry air × 57.73 lb dry air/min = 11.33 lb H_2O/min ✓

1,400 ft^3/min × 28.32 l/ft^3 × 1.4 mg NH_3/l × 0.001 g/mg × 1 lb/453.6 g = 0.122 lb NH_3/min ✓

$H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4$

H_2SO_4 98.07 lb/lbmole ✓ NH_3 17.03 lb/lbmole ✓

$(NH_4)_2SO_4$ 132.13 lb/lbmole ✓

0.122 lb NH_3/min × 1 lbmole NH_3/17.03 lb NH_3 × 0.5 lb mole H_2SO_4/lb mole NH_3 × 98.07 lb H_2SO_4/lb mole H_2SO_4

= 0.352 lb H_2SO_4/min ✓

Woodward-Clyde Consultants

Subject: Tank 102 Vent Gas Treatment NH_3 Scrubber Project No. 89C 114MM

By: J. Sroff Checked By: ESR Task No. 5

File No. -

Date: 4-30-92 Date: 5/27/92 Sheet 3 of 6

0.122 lb NH_3/min + 0.352 lb H_2SO_4/min
= 0.474 lb $(NH_4)_2SO_4$/min ✓

Air Out

57.73 lb dry air/min

Air at 60 °F, 100 % humidity, 24.6 in Hg

$H = 0.01108 + 0.00241 = 0.0135$ lb H_2O/lb dry air ✓
$V = 16.28$ ft³/lb dry air ✓

57.73 lb dry air/min × 0.0135 lb H_2O/lb dry air
= 0.78 lb H_2O/min ✓

57.73 lb dry air/min × 16.28 ft³/lb dry air = 940 ft³/min ✓

Blowdown Out

Must remove $(NH_4)_2SO_4$ produced in blowdown

0.474 lb $(NH_4)_2SO_4$/min

Blowdown at 5 % TDS including H_2SO_4 last

from page 1 pH = 2

$[H_2SO_4]$ = 0.005 gmole/l × 98.07 g/gmole
= 0.49 g/l ≈ 0.5 g/kg = 0.05 % TDS ✓

So blowdown will be approximately 5 % $(NH_4)_2SO_4$

5 % ammonium sulfate sp. grav = 1.028

0.474 lb $(NH_4)_2SO_4$/min × $\frac{1 \text{ lb blowdown}}{0.05 \text{ lb } (NH_4)_2SO_4}$ = 9.49 lb blowdown/min ✓

9.49 lb blowdown/min × 0.95 lb water/lb blowdown = 9.01 lb water/min ✓

9.49 lb blowdown/min / (8.33 × 1.028 lb/gal) = 1.11 gal blowdown/min ✓

1.11 gal blowdown/min × 3.785 l/gal × 0.49 g H_2SO_4/l × 1 lb/453.6 g
= 0.0045 lb H_2SO_4/min ✓

Subject: Tank 102 Vent Gas Treatment NH_3 Scrubber
Project No. 89C 114 MM
Task No. 5
File No.
Sheet 4 of 6

By J. Scott
Checked By ESR
Date 4-30-92
Date 5/27/92

Acid In

$0.352 + 0.0045 = 0.357$ lb H_2SO_4/min ✓

50 wt % sulfuric acid   sp grav = 1.395

0.357 lb H_2SO_4/min × 1 lb acid / .50 lb H_2SO_4
= 0.714 lb acid / min ✓

0.714 lb acid/min / (8.33 × 1.395 lb/gal) = 0.061 gal/min ✓

0.714 lb acid/min × 0.50 lb H_2O / 1 lb acid
= 0.357 lb H_2O/min ✓

Makeup Water In

Water Balance:

Air In	+ 11.33	lb H_2O/min ✓
Acid In	+ 0.357	" ✓
Air Out	− 0.78	" ✓
Blowdown Out	− 9.01	" ✓
Net	+ 1.897	lb H_2O/min ✓

Make-up water requirement −1.9 lb/min ✓
= −.22 gpm ✓

Summary for Scrubber # 1 Design basis

50% wt sulfuric acid = 0.714 lb/min ✓
= 0.061 gpm ✓

Blowdown (5 % wt $(NH_4)_2SO_4$) = 9.5 lb/min ✓
= 1.1 gpm

Make-up Water = < 1 gpm ✓

Subject: Tank 102 Vent Gas Treatment NH_3 Scrubber Project No. 89C114 MM
By J. Groll Checked By ESR Task No. 5
Date 4-30-92 Date 5/27/92 File No.
Sheet 5 of 6

Scrubber # 2

Air In

Air at 13,000 cfm, 40 °F, 24.6 in Hg, 60% humidity

$H = 0.00313 + 0.00069 = 0.00382$ lb H_2O/lb dry air
$V = 15.41$ ft^3/lb dry air

13,000 ft^3/min / 15.41 ft^3/lb dry air = 844 lb dry air/min

0.00382 lb H_2O/lb dry air × 844 lb dry air/min = 3.22 lb H_2O/min

13,000 ft^3/min × 28.32 l/ft^3 × 0.14 mg NH_3/l × 0.001 mg/g
× 1 lb/453.6 g = 0.114 lb NH_3/min

0.114 lb NH_3/min × 1 lbmole NH_3/17.03 lb NH_3 × 0.5 lb mole H_2SO_4/lb mole NH_3
× 98.07 lb H_2SO_4/lb mole H_2SO_4 = 0.328 lb H_2SO_4/min

0.114 lb NH_3/min + 0.328 lb H_2SO_4/min = 0.442 lb $(NH_4)_2SO_4$/min

Air Out

844 lb dry air/min

Air at 40 °F, 100% humidity, 24.6 in Hg

844 lb dry air/min × 0.00634 lb H_2O/lb dry air = 5.35 lb H_2O/min

844 lb dry air/min × 15.47 ft^3/lb dry air = 13,057 ft^3/min

Blowdown Out

0.442 lb $(NH_4)_2SO_4$/min

0.442 lb $(NH_4)_2SO_4$/min × 1 lb blowdown/0.05 lb $(NH_4)_2SO_4$ = 8.84 lb blowdown/min

8.84 lb blowdown/min / (8.33 × 1.028 lb/gal) = 1.03 gpm blowdown

8.84 lb blowdown/min × 0.95 lb H_2O/lb blowdown = 8.40 lb H_2O/min

Subject Task 10% Ha Gas Treatment NH3 Scrubber
By J. Scott
Checked By ESR
Date 4-30-92
Date 5/27/92
Project No. 89C114MM
Task No. 5
File No.
Sheet 6 of 6

1.03 gal blowdown/min x 3.785 l/gal x 0.49 g H_2SO_4 / l x
1 lb/453.6 g = 0.0042 lb H_2SO_4/min ✓

Acid In

0.328 + 0.004 = 0.332 lb H_2SO_4/min ✓

0.332 lb H_2SO_4/min x 1 lb acid/0.50 lb H_2SO_4 = 0.664 lb acid/min ✓

0.664 lb acid/min / (8.33 x 1.395 lb/gal) = 0.057 gal acid/min ✓

0.664 lb acid/min x 0.50 lb H_2O/lb acid = 0.332 lb H_2O/min ✓

Make-up Water In

Air In	+ 3.22	lb H_2O/min ✓
Acid In	+ 0.33	lb H_2O/min ✓
Blowdown Out	− 8.40	lb H_2O/min ✓
Air Out	− 5.35	lb H_2O/min ✓
	−10.2	lb H_2O/min ✓

Make-up Water 10.2 lb/min = 1.22 gpm ✓

Summary for Scrubber H2 Design Basis

50 wt % Sulfuric Acid = 0.664 lb/min ✓
= 0.057 gpm ✓

Blowdown (5% $(NH_4)_2SO_4$) = 8.8 lb/min ✓
= 1.0 gpm ✓

Make-up Water 1.2 gpm ✓

Subject Utility Water Solenoid Valve Selection

Project No: 89C 114 mm

Task No. 6

By WWI

Checked By

File No.

Date 6/18/92

Date

Sheet 1 of 1

1. water pressure at main = 50 to 57 PSI
2. Estimate 20 PSI Loss to sump fill valves and ≈ 0 press downstream
3. ΔP across valve ≈ 30 PSI
4. Assume min Fill time = 1 min @ 30 gal. ~~Sump~~
   Assume max. Fill time = 5 min. @ 255 gal. Sump

5. FLOW Required

$$\frac{255\text{ gal}}{5\text{ min}} = 51\text{ GPM (min)}$$

$$\frac{30\text{ gal}}{1\text{ min}} = 30\text{ gal/min (max)}$$

6. ~~[illegible]~~ =

$$C_v = \frac{GPM}{\sqrt{H}} = \cancel{[illegible]}$$

$$C_v = \frac{51}{\sqrt{30}} = 9.3\text{ min}$$ for large unit use 1" $C_v = 11.5$

$$C_v = \frac{30}{\sqrt{30}} = 5.5\text{ max.}$$ for small unit Use 3/4" CV = 5 for small unit

7. Selection

At Scrubber D101

Select ASCO Red HAT, Cat. No 8221 G7, Type 3R, N.C., C_v = 11.5
120/1/60, 1" NPT with 1" orifice Brass Body & Buna N DISC

At Scrubber D-102

Select ASCO Red Hat Cat. No 8030 G3, Type 3R, NC, CV = 5
120/1/60, 3/4" NPT with 3/4" orifice, Brass Body & Buna N DISC

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Subject: DESIGN ANALYSIS - EMISSION CONTROL DUCT | Project No. 89C 114 MM
By WWI | Checked By Joseph Scott | Task No. 5.3
File No. 7
Date 6/2/92 | Date 6/3/92 | Sheet 1 of 2

Design Criteria

1. Emission Control will be operated during two phases
   a) Phase 1 - Tank is virtually closed up. Ventilation is required to evacuate fluid vapors generated from heating, and what leaks into the tank
   b) Phase 2 Tank fluid has been removed, and an opening has been provided in the tank. Ventilation is provided to produce an in draft thru the opening in case there are additional gasses released. This ventilation will also provide some purging, but very little in the way of heat relief for personnel.

Design Conditions

A For Phase 1

Infiltration has been estimated to be about 1100 cfm, based on:

1. 1963 Ft. of Joints at an estimated 1/64" Crack
2. 0.55 Cfm / lin. Ft of Joint from Carrier design manual part 1 table 44B. assuming the cracks are similar to residential casement windows.
3. Since the temperature of air leaving the tank could rise to 140°F @ 100% saturated, volume would increase To 1360 cfm.

B For Phase 2

ventilation rate has been estimated using the Industrial Ventilation Manual by the ACGIH, for a fumigation booth (VS 921) as a guide, and modifying to suit.

1. ~~The~~ 20 air changes per hour are recommended for unprotected Personnel entry. ~~20 changes~~
2. At this rate, 60 minutes should be allowed before entry = 20 changes
3. Provide at least 100 FPM thru a loading door, or 500 FPM thru an air inlet door.

Our operation is a tank with personnel entry by people at level B protection. We would purge tank for 20 air changes prior to entry. Assume an 8x8 loading door at an inlet velocity of 200 FPM. this results in 12800 cfm (Say 13000 cfm). Since the tank has about 200,000 cu. ft of volume, this ventilation rate will only be about 4 Changes / hour. Since we need a 20 air change purge, we need 5 hours purge time

C. The air in the tank is assumed to be at 100% RH at 140°F There will therefore be condensation on the duct wall. Duct material should resist corrosion. During phase 2 temperature will be at ambient conditions

D. AIR must pass thru a packed tower scrubber at "H_2O press drop and a carbon adsorption unit. Press. drop thru carbon adsorption unit will be "H_2O for the 13000 cfm system, and "H_2O for the 1360 cfm system

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Subject DESIGN ANALYSIS		Project No. 89C 114 MM	
By WWI	Checked By JPS	Task No. 5.3	
		File No. 7	
Date 6/2/91	Date 6/3/92	Sheet 2	of 2

TYPE OF SYSTEM

Since there will be condensation on the duct walls, the duct material must resist corrosion.

TYPE OF EQUIPMENT

CONSIDERED -

Galvanized or aluminum would probably corrode considering the nature of the fluid that is "off gassing"

Stainless steel would probably not corrode but would be expensive

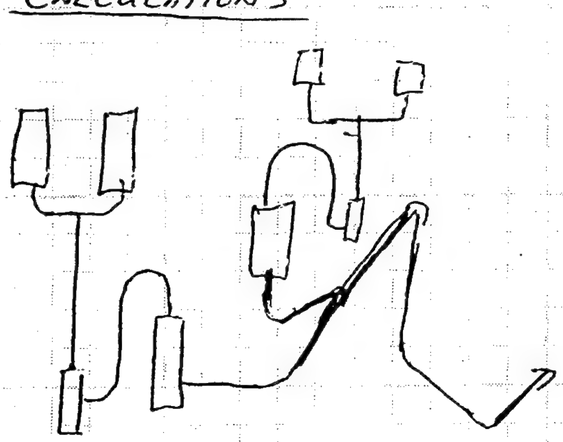
FRP ductwork would not corrode & be OK for temperature but is also expensive (though not like stainless)

CPVC ductwork will ~~take~~ withstand corrosion and the temperature it is less expensive than FRP; but doesn't come in sizes larger than 12"

Type G ductwork, which is a PVC backed with fiberglass reinforcement. Basically this is FRP ductwork. It will withstand corrosion and temperature

SELECTION - FRP (Type G) ductwork

CALCULATIONS



ITEM	DESCRIPTION TANK	CALC	PRESS LOSS
			0.1
1	Tank Exit	h = 0.5 VP VP - .60"	0.30
2	DUCT - 120'	@ .4"/100'	0.48"
3	90° Ells - 3	h = 0.55 x VP 3 times	0.99
4	45° Ells 1	h = 0.275 VP	0.17
5 -	Branch Exit 1		—
6.	SCRUBBER		2"
7.	Duct work 25'	@ .4"/100'	0.10
8	Double Elbow 1	h = .55 VP twice	0.66
9.	Elbow 1	h = .55 VP	0.33
10	Tee 1	h = 1.15 x 0.6	0.69
11	Ductwork 20'	4"/100'	0.08
12	CAG		10 or 6
13	Dischg 5'		.02
			3.92"

#2" Scrub.
10" CAG
Calculated
STD. Cond.

LOSS at ALT. & TEMP. CONDITIONS	13000	1300
SUCTION DUCT = $3.13 \times \frac{.066}{.075} \times \frac{1}{1.22}$ =	~~3~~ 2.6	.026 + say 0.074"
SCRUBBER	2.0	2.00
Dischg. Duct $0.79 \times \frac{.065}{.075} \times \frac{1}{1.22}$ =	0.6	.006
CAG	10.0	(or 6")
	15.2"	8.1" altitude conditions

select fans for ~~3.92~~ 4.0" SP ~~and~~ ductwork for large system and derate for HP

" " " 1.0" SP on ductwork for small system; derate for HP

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APPENDIX D
ELECTRICAL DESIGN CALCULATIONS

Subject RMA Tank DeCon Electrical Loads

By E Pitchkolan

Checked By

Date 6/23/92

Date

Project No. 89C114MM

Task No. 5

File No.

Sheet 1 of 2

Equipment	Hp/Pwr	Amperage	KVA	Starter Size
P101	20hp	34A	28 KVA	2
P102	20 hp	34A	28 KVA	2
P103	5hp	9.5A	8 KVA	1
P104	3hp	6 A	5 KVA	1
P105	3hp	6 A	5 KVA	1
P106	381W	3.3 @ 115VAC	Lighting Panel Load	NA
P107	381W	3.3 @ 115VAC		NA
BL101	40hp	65A	54KVA	3
BL102	7.5hp	14A	12KVA	1
Lighting Panel Transformer	15KVA	31.25A	15KVA	NA
Area Floodlights	4000W	8.33 A	4 KVA	NA
Tank Lights	4000W	8.33 A	4 KVA	NA
DeCon Trailer	25KVA	100A Service 240/120V 1Ø	25KVA	NA
Welding Receptacle		60A	50KVA	NA
H-101 Blower	15hp	26.25	22KVA	2
H-101 Circ Pump	40hp	65A	54KVA	3

Total Connected Load 314 KVA

Subject RMA Tank Delm Electrical Loads

By E Pitchkolan

Checked By

Date 6/23/92

Date

Project No. 89C114MM

Task No. 6

File No.

Sheet 2 of 2

Connected Loads vs. Max. Demand

P103 5hp } only one of these will operate at a time — 5hp - 8KVA

P104 3hp — 6hp - 10KVA

P105 3hp

BL101 - 40hp — 7.5hp - 12KVA

BL102 - 7.5hp — 40hp - 54KVA

BL101 will operate only after the tank is open and other processes are shutdown - BL102 will not run after the tank is open

---

Lighting - Tank lighting will operate only when the tank is open. -4000watts

54KVA
10KVA
4KW
68KVA

Connected Load 314 KVA
Independent Load 68 KVA
MAX DEMAND - 246 KVA

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Subject VOLTAGE DROP CALCULATIONS

By Ed Pitchkolan

Date 6/23/92

Checked By

Date

Project No. 89C114 MM

Task No. 6

File No.

Sheet 1 of 3

H101 SKID

2AWG 110 Amp Trip Breaker 50 ft distance

$Vd = IR(\cos\theta) + IX(\sin\theta)$

From Okonite Catalog Bulletin EHB-88 Tables 1-3

$$Vd = (110)\left(\frac{.169}{1000 ft.}\right)(50)(.8) + (110)\left(\frac{.05}{1000 ft.}\right)(50 ft.)(.6)$$

$Vd = .74 + .17$

$Vd = \frac{.91v}{480} = .2\%$

P101

#4AWG 50 Amp Trip Breaker 135 ft Distance

$$Vd = (50)\left(\frac{.269}{1000 ft}\right)(135)(.8) + (50)\left(\frac{.04}{1000 ft}\right)(135)(.6)$$

$Vd = 1.45 + .16$

$\% Vd = \frac{1.61}{480} = .34\%$

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Subject

By Checked By

Date Date

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Sheet 2 of 3

P102

#4AWG 50 AMP Trip Breaker 155 ft. Distance

$Vd = (50)\left(\frac{.269}{1000ft}\right)(155).8 + (50)\left(\frac{.04}{1000ft}\right)(155)(.6)$

$Vd = 1.67 + .19$

$\% Vd = \frac{1.86}{480} = .39\%$

D101

#2AWG 100 Amp Trip Breaker 100 ft. Distance

$Vd = 100\left(\frac{.169}{1000ft}\right)(100)(.8) + 100\left(\frac{.05}{1000ft}\right)(100)(.6)$

$Vd = 1.4 + .3$

$\% Vd = \frac{1.7}{480} = .35\%$

D102

#8AWG 40 AMP Trip Breaker 100 ft Distance

$Vd = 40\left(\frac{.679}{1000}\right)(100)(.8) + 40\left(\frac{.066}{1000}\right)(100)(.6)$

$Vd = 2.17 + .16$

$\% Vd = \frac{2.33}{480} = .5\%$

Subject

By

Date

Checked By

Date

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Sheet 3 of 3

DeCon Trailer

#4 AWG 70 AMP TRIP BREAKER 115 ft. Distance

$$Vd = (70)\left(\frac{.269\,\Omega}{1000ft}\right)(115)(.8) + 70\left(\frac{.04}{1000ft.}\right)(115)(.8)$$

$$Vd = 1.73 + .26$$

$$Vd = \frac{2}{480} = .42\%$$

Incoming Line

500 KCMIL 350 AMP TRIP BREAKER 60 FT.

$$Vd = 350\left(\frac{.0222}{1000ft}\right)(60)(.8) + 350\left(\frac{.044}{1000ft}\right)(60)(.6)$$

$$Vd = .373 + .554$$

$$\%Vd = \frac{.93}{480} = .2\%$$

Subject RMA TANK DECON BREAKER & CABLE

By E Pitchkolan

Date 6/24/92

Checked By

Date

Project No. 89C114MM

Task No. 6

File No.

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Equipment Grouped Together on skids

Cable Size (75°F)

① HE-101 None P-101 20hp		34A X1.25 → 42.5 ⇒ 50A BKR	#4AWG
② HE-102 None P-102 20hp		34A X1.25 → 42.5 ⇒ 50A BKR.	#4AWG
③ A-101 none BL-101 40hp P-103 5hp		74.5 X1.25 → 93 ⇒ 100A BKR	#2AWG
④ A-102 none BL-102 7.5 P-104 3 P-105 3		26 X1.25 → 32.5 ⇒ 40A	#8AWG
⑤ H-101 none Blower 15 Circ. Pump 40		84 X1.25 → 105A ⇒ 110A	#2 AWG
⑥ Lighting Tank 4000W		use Welding Outlet	# 6AWG
⑦ Welding Receptacle		60A existing	NA
⑧ 15 KVA XFMR		30A existing	NA
⑨ 25 KVA XFMR		52.A X1.25 = 65 ⇒ 70A	# 4AWG

Subject RMR Tank DeCon XFMR Sizing
By E Pitchkolan
Date 6/1/92

Checked By
Date

Project No. 89C114MM
Task No. 6
File No.
Sheet 1 of 1

TRANSFORMER SIZING

13.8KV to 480V, 3ϕ

260KVA required – 3-25KVA existing
change to 3-100KVA – for total of 300KVA
87% Maximum Loading.

DeCon TRAILER 480-240/120V, 1ϕ

100A Service @ 240/120V

100X240 = 24KVA – 25KVA XFMR

The Electrical Switchgear Rack has an existing 15KVA, 480-208Y/120, 3ϕ transformer that feeds the existing panel. This will be reused.